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THE PEAT RESOURCES OF WISCONSIN

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A PEAT BOG.

A SLANE OF THE OLDEN TIME, ABOUT 1760.

A MODERN SLANE.
(MADE BY O. AMES & SONS, NO. EASTON, MASS.)

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INTRODUCTION

Importance of Fuel Resources

For a number of years the attention of thinking persons has been turned to the rapid rate at which our fuel resources are disappearing. The wasteful and extravagant treatment of these resources has been the cause of grave concern. The federal government and many of the state governments have appointed commissions to investigate the situation and inventories are being made which will show the amount and value of these resources and their probable duration. Where power is developed from the combustion of oil, gas, wood or coal, these materials are destroyed. Our supply of natural gas and oil is uncertain and limited. Our forests, furnishing wood fuel, are rapidly disappearing. It has been estimated that, at the present rate of consumption, the supply of anthracite coal will be exhausted in about 100 years. In approximately 700 years the supply of bituminous coal will have been used up.* Hence the careful using of the present supply of high grade fuels and the discovery and utilization of new low grade fuels is of much importance to the future welfare of the nation.

Fuel in Wisconsin

At present Wisconsin is not numbered among the fuel producing states, as neither oil, natural gas nor coal are found within its borders. Originally the state was heavily forested and wood for fuel purposes was cheap and plentiful. The rapid settlement of the state, however, brought new and increasing demands for wood of all sorts for various purposes. Clearing of land and the great demand for lumber has depleted the supply of wood and it is now in most places more expensive than coal. Consequently coal has replaced wood as a fuel in this state and many of Wisconsin's industries are dependent upon coal for their operations. The great demand for coal, the rapidly diminishing supply, the limited areas of coal production, the cost of transporting to the consumers located at a distance from the mines, are factors which have gradually increased the price of this article of commerce. Owing to the constantly increasing demand, the cost will most likely increase continuously.

*Parker, E. W., "How long will our coal supplies meet the increasing demands of commerce?" U. S. Geological Survey. Presented before the American Mining Congress, 1907. See Mining World, Nov. 23, 1907.

In its water powers, as yet largely undeveloped, Wisconsin has a source of power that is of great economic importance.* While the development of the water powers will relieve the situation to some extent, certain lines of industry require not only power, but fuel as well. For this they are now dependent upon outside sources. Fuel must be imported, the nearest coal mines being in Illinois. But while Illinois is the largest coal producing state in the country, and probably contains more unmined coal than any other state in the country,† approximate estimates seem to indicate that, at the present rate of consumption, the coal fields of Illinois will be exhausted in about 100 years.§

Further, the problem of obtaining cheaper fuel for the manufacturer and the householder becomes more and more important with each recurring strike of the coal miners. These strikes and the resulting "coal famines" forcibly bring out the fact that both manufacturer and householder are greatly dependent upon the coal mining industry.

Thus, it may be seen that the close study of possible substitutes for coal is highly important to this state and cannot be begun too soon.

Wisconsin Peat Deposits a Possible Fuel Resource

Scattered over Wisconsin are many marshy areas and lowlands containing large deposits of peat. The possibility that this peat might some day be utilized for fuel and in various other ways has not been generally appreciated by the people of the state. Some years ago Wisconsin peat was used in a small way, in fact, several factories for the manufacture of peat fuel have been operated at various times. But thus far the development of the peat industry here has not been attended with success. Similar conditions have prevailed in Michigan and elsewhere in this country. In Canada the situation is not greatly different. But in Europe peat fuel and other peat products have been manufactured on an economical basis for a long time. There peat is used for both domestic and industrial purposes and the whole industry is upon a much firmer footing. Since peat has been used successfully elsewhere, it is natural to inquire whether or not Wisconsin peat can be put to similar uses.

*Smith, L. S., "The Water Powers of Wisconsin." Bull. No. XX., Wis. Geol. and Nat. Hist. Survey, 1908.

†Bement, A., "The Illinois Coal Field." Journal Western Society of Engineers, June 1909, p. 305.

§Ray, W. T., (U. S. Geol. Survey) Journal Western Society of Engineers, June 1909, p. 339.

Demand for Information on Peat

Announcements of projected peat operations appear in the public press from time to time and these serve to stimulate and renew interest in the development of the peat deposits of Wisconsin. The following editorial note, appearing in the Milwaukee Evening Wisconsin of September 22, 1909, is an illustration typical of such announcements:

> "There will be wide popular interest in the plan reported from Fond du Lac of putting the Lamartine Peat Light and Power Company in position to make fifty tons of peat briquettes a day in accordance with the process now successfully employed in Germany. There are millions of tons of available peat in the west, and one successful enterprise will inspire the establishment of many briquette factories that will materially influence the fuel market."

That there is much interest in this matter is shown by these announcements and by numerous requests from owners of peat bogs and other interested parties for information relating to the peat resources of the state and the possibility of their profitable development.

Purpose and Scope of This Investigation

The present bulletin was written in response to this demand and is the result of investigations undertaken with a view of discovering the location, extent and character of the peat beds of the state and of determining the value of the peat for various purposes. It indicates some of the uses to which peat may be put and gives information showing how peat has been and is being utilized elsewhere. The material was not selected for its scientific value alone but for its practical value also.

The subject of the possibilities of Wisconsin peat has been treated in a more or less general way and no claim for completeness of treatment is made. Much work remains to be done in making practical experiments which will demonstrate that Wisconsin peat can be used with profit commercially. Hence, it is recognized that this bulletin is only a first step toward furnishing the information of interest to the public.

Acknowledgments

Much of the material that has been used in this bulletin is original and represents the results of first hand studies that have been carried on somewhat intermittently since 1903. At the same time, pub-

lications of all sorts have been freely consulted. A partial list of these, given in the bibliography, together with the foot notes throughout, will sufficiently acknowledge the help received from them. General acknowledgment of help received from sources, not specifically mentioned elsewhere, is hereby made.

Specific acknowledgments should be made as follows:

The work was mostly done under the direction of W. O. Hotchkiss, State Geologist. Previous investigations had been made by this survey in co-operation with the College of Engineering of the State University.

The first series of special investigations were made in 1903 by Messrs. R. H. Hadfield and A. L. Johnson, students of the University of Wisconsin, under the direction of Prof. A. W. Richter. A thesis, entitled, "An investigation of the Peat Deposits in Wisconsin," contains the results of their work. This consisted of prospecting some of the more important peat deposits of the southern half of Wisconsin and, in addition, collecting and analyzing samples of peat from these deposits.

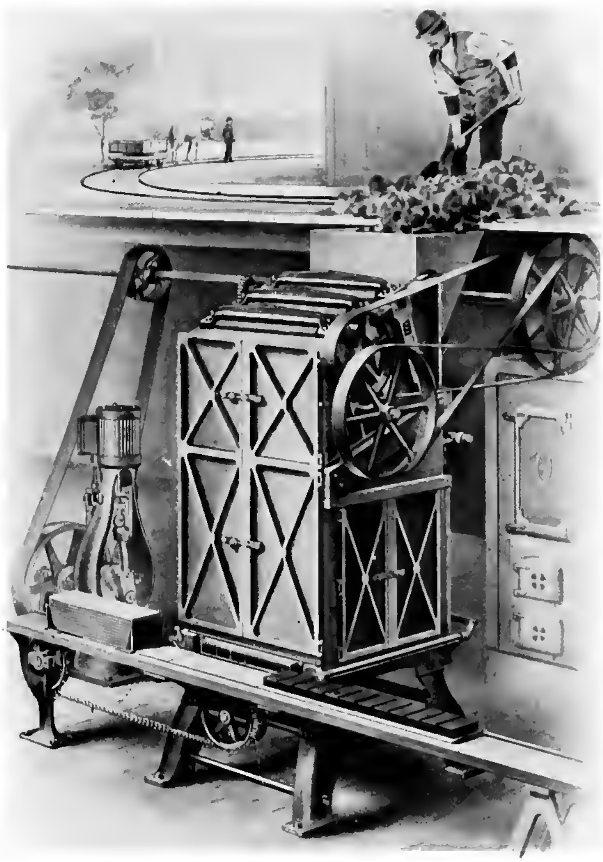
Some further special investigations were carried out subsequently, the results of which are recorded in the form of theses on file at the Library of the University of Wisconsin. The titles of these indicate the nature of their contents and are as follows:

> "The Manufacture of Producer Gas from Peat," by S. W. Cheney and L. B. Moorehouse, 1904.
>
> "An Analysis of the Products of Distillation of Wisconsin Peat," by W. J. Benedict and F. J. Saridakis, 1904.
>
> "Wisconsin Peat and Its By-products," by E. L. Leasman, 1907.

During the summer of 1908 additional studies, which had for their object the continuation of the prospecting work done in 1903, were made by the writer. Such portions of the state as had not already been prospected were examined, attention being paid particularly to the northern half. Prof. Chas. A. Davis, Peat Expert for the United States Geological Survey, accompanied the writer for about ten days at the beginning of the field season and made many valuable suggestions concerning prospecting methods, etc. Prof. Davis was engaged in similar investigations for the government and in this way the work of the United States Geological Survey and the Wisconsin Geological and Natural History Survey were brought together and conducted, as nearly as might be, along parallel lines. During the remainder of the summer the writer continued the prospecting alone.

Co-operative arrangements were made, as a result of which the Wisconsin Survey sent samples of the peat collected in the field to the United States Fuel Testing Station at Pittsburg for analysis and examination. In return, analyses of these samples were made by the government and the results of same supplied to the Wisconsin Survey. Further, franking privileges, material for mailing samples from point to point, etc., were supplied by the United States Geological Survey to the Wisconsin Survey.

The preparation and arrangement of material for publication, including the making of photographs, drawings, etc., was done by the writer at such times as could be spared from other duties during the period 1908 to 1915.



LEAVITT'S PEAT CONDENSING AND MOULDING MILL.
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PART I

PEAT, ITS ORIGIN, OCCURRENCE, CHARACTERISTICS AND UTILIZATION

CHAPTER I

PEAT—ITS ORIGIN, OCCURRENCE AND CHARACTERISTICS

Composition of Vegetable Matter and its Decay

All organic matter is made up of a few elementary substances. Carbon, hydrogen, and oxygen, in various combinations, are the principal elements composing vegetable matter, while nitrogen, sulphur and a few metallic elements in small quantities make up the remainder. Thus, in woody matter, such as the leaves and stems of plants, there are found compounds of carbon, hydrogen, and oxygen like cellulose ($C_6H_{10}O_5$) and woody-fibre or lignin ($C_{35}H_{24}O_{20}$).

When vegetation dies or falls to the ground the presence of air and moisture permit a destructive action to begin upon it. The chemical substances, due to their complex structure, are unstable compounds, and, under favorable conditions of air, moisture and temperature, break down into simpler compounds. Microscopic plants, such as fungi and bacteria, begin to grow and live upon the decaying vegetation and convert it to their own use for growth and nourishment.

Under extremely favorable circumstances the fungi and bacteria will thrive and rapidly reduce the vegetable material into simple gaseous compounds such as carbon-dioxide (CO_2), ammonia (NH_3) and water (H_2O), and a residue which soon becomes a part of the soil. Less favorable surroundings, such as submergence under water, will not permit some of these microscopic plants to exist, while others live under difficulties. The decomposition then progresses slowly and incompletely, the more unstable chemical compounds vanishing while the more stable ones remain practically unchanged. Thus, the nature of the decomposition and the rate at which it takes place, as well as the consequent chemical and physical changes of structure of the material, depend largely upon conditions. Under the conditions favorable for peat formation, the vegetable structures become decomposed or even disappear entirely. A large part of the hydrogen and oxygen and a relatively small part of the carbon are given off as volatile gases, so that the net result is the enrichment of the peat in carbon. Carbon dioxide (CO_2) and marsh gas or methane (CH_4) are two of the principal gases resulting during this process.

Peat a Product of Decayed Vegetation

As this material collects it becomes subjected to compression, to slow carbonization, to permeation by bituminous and resinous substances, and after a time becomes what is known as peat. Webster's Dictionary defines peat as "a substance of vegetable origin, consisting of roots and fibres, moss, etc., in various stages of decomposition, and found, as a kind of turf or bog, usually in low situations, where it is always more or less saturated with water."

Many varieties of it may be found. In its normal condition it contains large amounts of water, sometimes as much as 80 or 90 per cent. Some kinds have a light brown color, are very coarse in texture and resemble moss or other vegetable litter. Other forms, dark-brown or even black in color, present a muddy, sticky and clay-like appearance. This latter type can be moulded into any desired shape and when dried forms the peat briquettes of commerce. Between these two extreme types peat may take on a variety of colors, textures and structures. In fact, in most deposits of peat, several varieties may be found. Thus, near the top there may be a light-colored, coarse and loose, spongy, mosslike and partially decomposed peat containing fairly well preserved remains of the vegetation from which the peat was formed. The lowest layers of the deposit consist of dark-colored, black, fine and dense, compact, claylike, thoroughly decomposed peat containing less moisture, and in which the plant remains are no longer distinguishable except with the aid of a microscope. From the top to the bottom layers there may be a gradual and progressive change in color and texture.

Peat Bogs, Marshes and Swamps.

Decayed vegetation and peaty material of the kind just described accumulate in situations which are always moist and covered with water. Rolling land, containing undrained or poorly drained depressions, is very favorable for the occurrence of peat. As a result of this lack of drainage and accumulation of vegetable material bogs, marshes and swamps are formed. Davis* has described these types of peat deposits as follows: "A *bog* is an area of wet, porous land, on which the soil is made up principally of decayed and decaying vegetable matter, so loosely consolidated, and containing so much water, that the surface shakes and trembles as one walks over it. The vege-

*Davis, C. A., Peat and Its Origin. Geological Survey of Michigan, Annual Report, 1906, p. 109.

tation upon the surface is variable, but it is characteristically either some species of moss or of sedge, or grass, or a combination of two or more of these with shrubs and even small trees." "A *marsh* has a firm soil; that is, not easily shaken when walked upon, although it may be soft and very wet, even submerged, and the vegetation upon it is principally grass-like; that is, with long narrow leaves, and weak, short-lived aerial stems. Shrubs may occur on marshes, and where they are present not infrequently form thickets. * * * In marshes of this character the depth of peat may be slight or considerable." "A *swamp*, according to the writer's usage in this paper, has trees and shrubby plants as the most important part of the vegetation, the soil being, as in the case of the marsh, firm, but wet, even, at times, to flooding."

For examples and descriptions of these types of deposits see Chapters V and VI. Thus, deposit 305, at Waupaca, is a typical bog; deposit 304 illustrates a peat marsh at Waupaca; and deposit 306, located at Kiel, is a representative swamp.

Davis says further: "These types all intergrade more or less among themselves, and with swamps and marshes in which the soil is not of vegetable origin; hence no absolutely sharp differentiation can be made unless a rather elaborate set of compounds be devised. Not infrequently the three types may exist in the same basin and * * * it is possible to pass from one type to the other * * *."

Nystrom† has classified peat bogs into high bogs and low bogs and describes them as follows:

High Bogs.—The vegetable matter forming these bogs is principally made up of the remains of mosses, heath plants and of forest residue. On account of the moisture absorbing property of the sphagna in particular, these bogs are like enormous sponges, retaining large quantities of water, which furthermore favors the growth of this vegetation. Under favorable conditions these bogs may attain considerable depth, especially in their central parts, where the drainage is less and the growth of the moss more profuse. In many instances these parts are on a higher level than the rest of the bog and are often from 15 to 50 feet or more in depth.

Low Bogs.—The vegetable matter forming these bogs is made up of the remains of plants requiring more nourishment than the plants forming the vegetation of a high bog. The principal vegetation on low bogs is grasses, sedges, reeds and rushes.

†Nystrom, E., Peat and Lignite, Their Manufacture and Uses in Europe. Canada Dept. of Mines, Ottawa, 1908, p. 11.

Low bogs chiefly occur in localities which are occasionally or periodically flooded. In a great number of cases the conditions under which a bog has been formed have changed from time to time, resulting in different vegetation and in peat of different qualities. Bogs of this nature are classified as mixed bogs.

All of these types of bogs, marshes and swamps are found in Wisconsin and the classifications of Davis and Nystrom cover them almost exactly. In the northern part of Wisconsin the "high bog" type seems to predominate, while the "low bog" predominates in the southern part. In fact, there seems to be a more or less distinct line south of which the high or moss bog is not found. Hence the terms "northern" and "southern" types of bog have sometimes been used.

Conditions Essential to Peat Formation.

Certain climatic, topographical and meteorological factors combine in various ways to produce conditions favorable for the formation of peat. Not only do they either encourage or retard the growth of living peat forming plants but they also regulate the conversion of dead vegetation into peat. The relations existing between these factors are complex and all are more or less dependent upon one another. These conditions are briefly outlined below.

Air.—In order that dead vegetation may be converted into peat certain conditions of air supply are essential. Where the peat forming material is submerged in water so that access of air is restricted, the growth of organisms which produce rotting is hindered and the humification process then goes on normally. On the other hand, too much air will cause these bacteria to thrive and the vegetation, instead of being converted into peat, rots and soon becomes a part of the soil. Further, free access of air tends toward a gradual oxidation or slow burning of the materials. It is thus seen that a restricted air supply is one of the chief essentials of peat formation.

Water.—Together with air, water is of great importance. Peat rarely forms except in wet areas, such as ponds, swamps, or any place saturated or covered with water more or less permanently. For the growth of peat forming plants in profusion, plenty of water is required, but, at the same time, it must not be too plentiful. Not only is water required to nourish the peat forming plants while living, but it also performs the function of preserving the dead vegetation against the destructive action of too much air.

Humidity.—The moisture-absorbing capacity of the air in the vicinity of peat deposits exercises a considerable influence upon peat formation. Air which is relatively moist retards evaporation of water from the surface of bogs, while dry air causes the rapid drying out of the soil moisture. In addition, a continued and sufficiently humid atmosphere in the neighborhood of wooded moors often encourages the growth of mosses. This is not the case in the open country where the air is drier.

Rainfall.—It is found that regions, in which the rainfall is heavy and distributed at regular intervals throughout the year, usually have extensive peat deposits. Peat is rarely found in situations where there is a scarcity of rainfall or where dry periods predominate. If peat does occur in such places water is furnished by springs or by seepage from a distant source. It is also essential that the precipitation be retarded in its run-off, that is, the drainage must be poor. In long protracted periods of no rainfall marshes often become dry, begin to burn, and a destruction of peat results.

Sunshine.—The vegetation of any particular district is greatly influenced in its development by the quantity of sunshine which it receives. In order that enough peat-forming plant remains may collect, a long, mild season is required during which vegetation will be enabled to grow in plenty. Certain conditions of temperature, light and heat, directly dependent upon sunshine, are needed by all plants for growth. The sun also controls, to a large extent, the rate of evaporation of moisture from a bog. Sunshine and other factors combine to produce temperatures that are neither too high nor too low for peat formation. If the temperature is too great, vegetable matter will rot, while too much cold retards the growth of vegetation. Living plants also depend upon the sun for the heat which they need. The amount of light received by plants limits their growth, some of them being benefited by much light while others are injured by too great an amount.

Topography.—The configuration of the surface of the ground plays an important part in creating favorable situations for the formation of peat. Any depression in the earth's surface, capable of retaining a body of water, such as a lake or pond, is a possible site for a peat deposit. Hence peat is found abundantly in lacustrine areas and lowlands, though it may exist in poorly drained hilly or mountainous regions where the atmosphere carries a great deal of moisture. Glaciated areas with their uneven and rolling surfaces, ridges, moraines, gravel and till plains, etc., in fact, any areas in which there is a ten-

dency for water to accumulate in depressions, are fertile fields for the development of peat deposits.

Soil.—Depressions of this kind soon accumulate a deposit of soil in which aquatic and peat forming plants thrive and after the growth and death of many generations of plants a deposit of peat develops. Such soils are usually made up of non-permeable materials like clay which retain the water and if the bottom of the depression contains a soil, like sand, which would permit the water to percolate and run off easily, the subsoil will be one which prevents drainage. The physical and chemical peculiarities of the soil, from which the roots obtain their food, determines the types of plants which will grow in a given locality. Their character and distribution are largely controlled by the nature of the soil.

Growth of aquatic plants.:*—In order that material for peat formation may collect, it is essential that there be a luxuriant annual growth of aquatic and moisture loving plants. The vegetation characteristic of peat may be roughly indicated thus:

Mosses; sphagnum, hypnum and other varieties.
Heath-plants; cassandra, andromeda, etc.
Forest residue; roots, trunks and leaves of trees.
Grasses; cotton grass, wool grass and other grasses.
Sedges; including several varieties.
Aquatic and swamp plants; reeds, rushes, cattails, pond lilies, and various other kinds of water plants.

Geographical Distribution of Peat

Peat abounds in those portions of the earth which are usually damp and cool. The most extensive deposits seem to occur in the northern hemisphere, though deposits of great size exist in South America also. Large quantities of peat are found in the northern sections of Europe, Asia and North America. The peat beds of Scotland, Ireland, Germany, Austria, France, Holland, Denmark, Sweden, Norway and Finland, as well as those of Russia, have been exploited for many years. According to reports, Canada has more than 37,000 square miles of peat averaging from 5 to 10 feet in depth. In the United States peat bogs are common, large areas being located in Maine, Massachusetts, New York, Pennsylvania, Michigan, Wisconsin, Minnesota, Virginia, North Carolina and California.

*See Chapter III. p.61. See also Davis, C. A., "The Formation, Character and Distribution of Peat Bogs in the Northern Peninsula of Michigan." Geological Survey of Michigan, Annual Report, 1906.

In many countries peat is being utilized on a fairly large scale for domestic and industrial purposes. It is used for cooking and heating and in metallurgical processes, in steel and glass furnaces, as fuel in locomotive and stationary boilers, and for conversion into gas and the generation of power.

Quantity of Peat Available in the United States*

"So little information has been obtained in regard to the area and depth of the peat deposits in the United States that an accurate estimate of the quantity available is impossible. On the assumption that there are in the United States, exclusive of Alaska, 139,855 square miles of swamp lands,† it is estimated that 8 per cent of this area, or 11,188 square miles, will have peat deposits of good quality. Assuming further that the average depth of the peat in this area is at least 9 feet, and that the average yield will be 200 tons of salable fuel per acre for each foot of depth, the total available fuel in these deposits will reach 12,888,500,000 tons: this quantity, if converted into machine-peat bricks and sold at $3 per ton, would have a value of $38,665,700,000—no mean resource, but one that would furnish heat and power for the entire country for many years."

Peat is Incipient Coal

Peat is really incipient coal, that is, coal in its early stages of formation. Several things seem to point to this conclusion.

The known coal deposits were formed ages ago in a manner much like that in which peat bogs are now being developed. Just as peat is the result of the transformation of vegetable matter, mainly woody-fiber, so coal is the fossil remains of prehistoric vegetable growth.

A microscope, and sometimes even the unaided eye, will reveal the remains of ferns, of leaves and stems of plants and portions of trees in peat as well as in coal. Hence, a great similarity between the origin of peat and coal is indicated.

"The plants concerned in the production of coal vary considerably in different geological periods. In the coal measures proper, acrogens, ferns, equisetums, and similar allied forms are most abundant. It is stated by some observers that entire beds of coal are sometimes made up of spores of ferns. * * * In the coals

*Davis, C. A., Bull. 16, U. S. Bureau of Mines, 1911, p. 12.

†Senate Document, 151, 60th Congress, 1st session.

of newer date exogenous wood and leaves are more common than in those of the coal measures."* The peat forming vegetation consists of mosses, heath-plants, trees, grasses, sedges and various kinds of aquatic plants. In fact, the remains of cryptogams or coal forming plants can be detected in both coal and peat.

In the transformation of vegetable material, consisting principally of woody fiber, into the higher forms of fuel, the oxygen and hydrogen content have been partly reduced while the carbon content has been increased. The table below brings out this point.

TABLE 1.

Approximate Chemical Changes, Wood Fibre to Anthracite Coal.†

Substance	Carbon Per Cent	Hydrogen Per Cent	Oxygen Per Cent
Wood fibre	52.65	5.25	42.10
Peat	59.57	5.96	34.47
Lignite	66.04	5.27	28.69
Earthy brown coal	73.18	5.58	21.14
Bituminous coal	75.06	5.84	19.10
Semi-bituminous coal	89.29	5.05	6.66
Anthracite coal	91.58	3.96	4.46

Here it is seen that as the material becomes more nearly like coal the percentage of carbon it contains becomes greater. In other words, the material becomes carbonized. The hydrogen decreases slightly, while the oxygen diminishes very materially.

*Encyclopedia Britannica. Coal.

†Stirling, "A Book on Steam for Engineers." p. 111., by the Stirling Consolidated Boiler Company.

A chart bearing upon the origin of peat and the transformation of woody material into coal is here given. This chart was prepared from data given by Prof. Klason, of Stockholm, Sweden, and shows the average composition of different kinds of fuel, together with the mean calorific value of the absolutely dry and ash free fuel and the average percentage of moisture in its air dried state.* Here again similar conditions are observed concerning the carbon, hydrogen

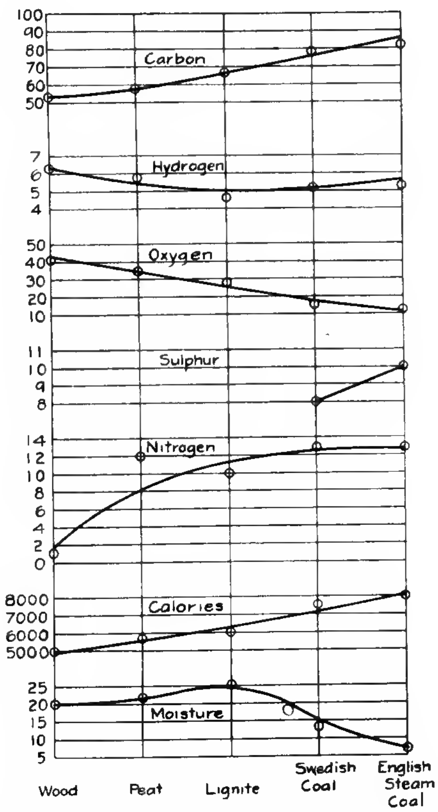


FIG. 1. TRANSFORMATION OF WOODY MATERIAL INTO COAL

and oxygen characteristics. There is an increase in nitrogen also and the heating value becomes greater. In addition, the lower curve on the figure shows the amount of moisture contained in the air dried fuel. It is greater in peat and lignite than it is in either wood or coal.

*Klason, Teknisk Tídskrift, 1896. Also Nystrom, E., "Peat and Lignite. Their Manufacture and Uses in Europe," Canada Dept. of Mines. Ottawa, 1908. p. 14.

Another table of analyses which shows the composition of sphagnum moss, oak wood, New Jersey peat and Illinois coal is given below. It also shows the gradual increase in the percentage of carbon that takes place in the changing of the vegetable matter to peat and its conversion to bituminous coal.

TABLE 2.

Comparative Table of Analyses.

Moss, Wood, Peat, and Coal.

Material	Carbon Per Cent	Hydrogen Per Cent	Oxygen Per Cent	Nitrogen Per Cent
*Sphagnum moss	49.88	6.54	42.42	1.16
*Oak wood	50.60	6.00	42.10	1.30
*New Jersey peat	58.00	6.36	31.85	1.14
†Illinois coal	65.48	5.09	15.04	1.39

The similarity between the composition of sphagnum moss and oak wood will appear from the table, and the decrease in the proportion of oxygen as that of the carbon content increases will also be observed. Ten to 12 per cent more of carbon and 10 to 12 per cent less of oxygen than the vegetable matter from which it was formed is contained in the best grades of peat.

In the book "Mechanical Draft" by the Sturtevant Co., the close relations existing between coal and peat are shown in the following manner. "It (coal) is a fossil fuel for whose existence geology thus accounts: During that period of the earth's formation known as the carboniferous age, vegetation was rank in the extreme. The atmosphere contained an amount of carbonic acid far in excess of that now present. The presence in the atmosphere of this excess of carbon, which is the food of the plants, as well as the temperature and the climatic conditions, were all favorable to the most prolific development of plant life. Age after age was employed by this vegetable growth in freeing the atmosphere from carbonic acid, and in storing up the potential energy of the sunlight as woody fibre in the form of carbon, separated from oxygen. By this continuous process of

*Reis: 21 st. Report of the State Geologist of New York, 1901, pp. 58 and 61.
†Savage: Bull. No. 2, Iowa Geol. Survey, 1905, p. 28.

growth and death of vegetable matter the earth became strewed with the remains, which were gradually compacted into peat beds of enormous extent. With succeeding climatic and geological changes, these peat beds, one after another, became submerged and overlaid by thousands of feet of sandstone, limestone and slate. Under the tremendous pressure thus exerted the peat beds were compressed and converted by successive stages into lignite, brown coal, gaseous coal, bituminous coal and semi-anthracites."

Thus, "a regular gradation can be traced beginning with peat or wood and passing through lignite, bituminous coal, anthracite and even graphite, the various stages of the process depending upon the degree of pressure or heat which has been exerted; and doubtless the peat bogs of today, if not sooner consumed, may in subsequent ages be metamorphosed into seams of coal for the benefit of the coming man."*

Davis† writes, "Although there have been many explanations of the origin of coal, the consensus of opinion of numerous writers is overwhelmingly in favor of the hypothesis that coal of all ages has been formed from peat. * * * It should be understood, however, that in the lapse of the enormous length of time since the older coals were formed, conditions have, perhaps, become less favorable for the growth of plants, as well as for their accumulation, and especially for the preservation of their remains, so that the peat deposits of the present are small in comparison with those of past geological ages from which the larger coal beds have originated. These facts being granted, it still remains true that in the present-day peat deposits are recorded the processes by which the coal-forming materials were segregated from the atmosphere and soil, were preserved, and started on the physical and chemical changes through which crude vegetable matter must ultimately pass to become coal. Peat may be considered the youngest stage of the transition of the solid plant-growth products into coal; by inference, therefore, peat is very young coal."

Concerning the origin of coal, White†† has to say as follows:

"The fact is almost universally accepted that beds of coal represent accumulations of vegetal matter in varying stages of preservation, with, as a rule, very small proportions of the remains of animal life. Mingled with the organic substances are different inor-

*Carter, W. E. H., 12th Report of the Bureau of Mines: Ontario, 1903. p. 193.

†Davis, C. A., "Origin and Formation of Peat." Bull. 38, U. S. Bureau of Mines, 1913 p. 165

††White, David. Bull. 38, U S. Bureau of Mines, 1913, p. 1.

ganic mineral sediments, which, together with the mineral matter originally contained in the plants themselves, constitute the "ash" of coal. The examination of coal shows that the kinds of ingredient plants range all the way from algae and fungi to large trees of various orders, and that these in turn vary in their own groups according to the depth and the nature of the water in which they grew and according to the other conditions of growth, such as moisture, temperature, soil, light, climate, and the competition of individuals. The species or kinds of plants and the numbers of each kind also differ greatly among themselves, not only during any one geologic period because of the changes of environment, but also from one geologic period to another, and it will be remembered that well-developed coal has been found in the strata of every period since the Silurian.

"Most geologists now agree that coal is transformed peat. True, there is wide difference of opinion as to how the transformation has been accomplished and even as to whether coal started as such peat as is now found. Some writers insist that the higher grade coal, in its process of development, never passed through geologic stages of existence as peat, lignite, etc., but these writers are relatively few. At all events there is scarcely anyone who does not admit that some peat has been converted to coal in the normal geologic processes. * * *

"The plant materials composing coal differ both in kind and in degree of preservation, or, rather, of decomposition, for it will be recalled that all the organisms forming the deposit undergo more or less decay, the extent of which depends on climate, water table, and other conditions of deposition, just as in the peat swamps of the present day. The rate and the extent of the decay are controlled largely by the oxygen supply, which is chiefly affected by the rate of plant growth, temperature, the exposure to the air, the drainage, and so forth. Obviously the growth of the peat accumulation requires that the rate of contribution of the plant material shall, on the whole, exceed the rate of decay, the putrefaction being finally smothered by exclusion of oxygen from the buried débris or stopped by the influence of the toxic products of decay accumulating beneath the surface of the bog.

"The process must take place beneath a water cover, preferably stagnant, or in the presence of sufficient moisture to prevent the vegetal matter from forming merely vegetable mold or humus. In some cases all the tender and delicate structures have disappeared, leaving only the most indestructible débris, such as the

grains or lumps of resin left by the completely decayed wood of certain conifers, fragments of hard and resistant cuticles, tough and oily seed coats, and gummy spore envelopes. On the other hand, much of the accumulated material may have decayed relatively little, and the vegetal mass composing the main substance of the coal may consist largely of wood, or, rarely, it may contain tender and delicate tissues of miscellaneous types, including fungi and possibly even algae."

Thiessen* draws the following conclusions based upon an extensive microscopic study of coal.

"All coal was laid down in beds analogous to the peat beds of today.

"All kinds of plants, especially such species as were adapted to the particular region where the deposit was located, in whole or in part went into the deposit.

"Plants are composed chiefly of cellulose and proteins. The former, comprising by far the larger bulk, constitute the framework, whereas the latter are concerned in the vital functions. With these are associated many other substances, among which are chiefly starch, sugars, and fats and oils, constituting reserve foodstuffs; waxes, resin waxes, resins, and higher fats, performing mainly protective functions, as in cuticles, spore exines, pollen exines, bark, cork, and waxy coverings; and resins and gums that are exuded as waste.

"These components differ very widely in their resistance to various agencies. Those substances involved in the life function and the support of the plant are relatively labile, whereas the others are relatively very stable under the conditions imposed upon them.

"At the death of the plants, governed by conditions imposed in the bog, a partial decomposition, maceration, elimination, and chemical reduction begins, brought about by various agencies, chiefly organic, mainly fungi at first and bacteria later. The most labile are removed first, the more resistant next, and so on as the conditions require, leaving the most resistant behind in a residue called peat, but still containing a large amount of cellulose, possibly in a somewhat changed condition.

"The process of decomposition, elimination, and chemical reduction begun in peat, chiefly by biochemical means, is taken up and continued by dynamochemical means into and through the various successive later stages, and results in the various grades of coal, as

*Thiessen, Reinhardt, Bull. 38, U. S. Bureau of Mines, 1913, p. 303.

lignite, sub-bituminous, bituminous, and cannel coal, and anthracite.

"Coal, then, is chiefly composed of residue, consisting of the most resistant components of plants, of which resins, resin waxes, waxes, and higher fats, or the derivatives of the compounds composing these, are the most important.

"The degree of decomposition, elimination, maceration, chemical reduction, and constitution, in any one stage, depends on the species, kinds of parts, organs, and products contributing to the deposit originally; the efficiency and duration of action, chiefly of the biochemical agencies, during the peat stages; and the efficiency and duration of action of the dynamochemical agencies during the coal stages.

"The greater the efficiency of the agencies during the biochemical stages, and the longer the time of their activities, the greater is the maceration, the concentration, and the reduction of the most resistant components.

"The greater the efficiency of the agencies during the dynamochemical stages, the greater is the concentration and chemical reduction of the most resistant components.

"Any algal or gelosic theory regarding the origin of coal has not been demonstrated."

For further material bearing on the origin of peat and coal the reader is referred to a very interesting series of articles contained in Bulletin 38, U. S. Bureau of Mines, 1913.*

Rate of Peat Formation

It is difficult to make a satisfactory calculation showing the rate at which peat forms. It is known that this rate is slower in cold climates than it is in warm climates. Further, the amount of plant material added to the peat deposit is greater in tropical climates than in the cold climates. Various authorities have attempted to arrive at the rate of peat formation and the following statement by White† may be cited as an example.

*Bulletin 38, U. S. Bureau of Mines, 1913.
White, David. "Physiographic Conditions Attending the Formation of Coal," p. 52.
White, David. "Rate of Deposition of Coal," p. 84.
White, David. "Regional Metamorphism of Coal," p. 91.
Davis, Charles A. "Origin and Formation of Peat," p. 165.
Thiessen, Reinhardt. "Microscopic Study of Coal," p. 187. (This paper contains a review of the writings of various authorities on the theories of coal formation.)

†White, David. "Rate of Deposition of Coal." Bull. 38, U. S. Dept. of Mines, 1913, p.87.

"The recorded observations as to the rate of peat growth differ widely and are in part conflicting. It appears fairly clear, however, that under very favorable conditions (or as a maximum under normal conditions) a foot of peat may be deposited on the surface of the bog in 10 years. But on account of continued bacterial action in furthering the decomposition of the underlying peat, and on account of the compacting of the peat under the superposed younger peat layers, the thickness of a 10-year growth of surface peat is gradually very greatly reduced, according to the depth in the bog, the conclusion being that at a depth of 15 to 20 feet 1 foot of surface peat will possibly be reduced to about $1\frac{1}{8}$ inches of peat. It is therefore necessary to employ only deep-peat deposits in drawing analogies with coal of workable thickness. Also, it is recognized that in most cases the rate of increase in the depth of the peat is very much lower. However, it seems to be the conclusion reached by many students of peat bogs that, on the whole, the rate of peat deposition in the average bogs of the north temperate zone is probably nearly equivalent to 1 foot of peat per century at a depth of about 18 feet. Data really ample for thorough or trustworthy time deductions, satisfactory for general application, do not seem to have been collated."

Peat Classified According to Physical Characteristics

A German writer cited by Johnson* has classified peat in the manner shown in the following.

(a) *Turfy peat.*—Consisting of slightly decomposed mosses and other peat-producing plants, having a yellow or yellowish brown color, very soft, spongy, and elastic; specific gravity, 0.11 to 0.26, the full English cubic foot weighing from 7 to 16 pounds.

(b) *Fibrous peat.*—Unripe peat which is brown or black in color, less elastic than turfy peat, the fibres either of moss, grass, roots, leaves or wood, distinguishable by the eye, but brittle and easily broken; specific gravity 0.24 to 0.67, the full cubic foot weighing, accordingly, from 15 to 42 pounds.

(c) *Earthy peat.*—Nearly or altogether destitute of fibrous structure, drying to earth-like masses which break with more or less difficulty, giving lusterless surfaces of fracture; specific gravity, 0.41 to 0.90, the full cubic foot weighing from 25 to 56 pounds.

(d) *Pitchy peat.*—Dense; when dry, hard; often resisting the blows of a hammer, breaking with a smooth, sometimes lustrous fracture into sharp-angled pieces; specific gravity, 0.62 to 1.03, the full cubic foot weighing from 38 to 65 pounds.

*Johnson, S. W., Peat and Its Uses. p. 95-96.

Physical Characteristics

As peat occurs in undrained bogs it is made up of partly decayed and disintegrated vegetable material and of water amounting to from 80 to 95 per cent of its weight. The vegetable material is derived from a variety of plants. Peat is extremely variable insofar as different deposits are concerned and even in different parts of the same deposit.

Color.—In color peat may be yellow or straw-colored, all shades of brown, and black. It may take on any color ranging from straw to black. In fact, it frequently changes its color during the process of drying. Often it has a gray appearance or is spotted with white due to the presence of small shells and remains of crustaceans. Again, the form known as alga1 peat is greenish gray in color. Sometimes, also, the presence of mineral matter may discolor the peat.

Texture.—The plants which formed the peat in any particular deposit determine its texture to a considerable extent. If the peat was formed from trees, shrubs and bushes it is likely to be woody. If formed from grasses and sedges it usually has a fibrous texture. Very commonly the peat is so thoroughly decomposed that it is dense and without structure. Algal peat has a cheese-like consistency.

Composition.—Peat is made up of both solid and liquid matter. The *solid* matter contains organic and inorganic constituents. The organic constituents are made up largely of material accumulated by the life processes of plants and animals. Carbonaceous, combustible portions of the organic constituents are of vegetable origin and come from the woody and fibrous materials of the leaves, stems, roots, etc., of the vegetation from which the peat was formed. The non-combustible portions of the organic materials, or mineral portions, are collected and deposited by the plants themselves. Further, certain animals supply matters of an organic nature as is evidenced by the fact that the remains of both large and small animals are found in peat deposits. Among these may be mentioned bones and teeth of large extinct mastodons, elephants, mammoths; smaller animals like frogs, snakes, fishes, birds; still smaller animals like bugs and spiders; down to the minute microscopic marine animals and crustaceans. Lime and silica in peat come from such sources. In addition, inorganic mineral matter not directly traceable to organisms is brought in by water and ice. Rains, overflowing streams, and the like, cause erosion of the surrounding soil and carry rocks, stones, pebbles, sand, and mud into the deposit. This material may

be either in suspension or in solution. Water passing over certain soils and rocks also dissolves some of the minerals which they contain and brings them to the deposit in solution. Iron, magnesium and calcium salts are precipitates of minerals carried into deposits in this way.

The wind, also, contributes its share toward carrying dust and sand into peat deposits.

The *liquid* contained in peat is, of course, water.

Weight, Density, and Specific Gravity.—The weight per unit of volume, or density, and the specific gravity of peat varies considerably. This might be expected, of course, from the fact that the peat varies so much in texture and composition.

Under the heading "Peat Classified According to Physical Characteristics" are given some data concerning these properties. The weight per cubic foot varies from 7 pounds to 65 pounds. The specific gravity, or weight compared with an equal volume of pure water (the sp. g. of which is 1.000) is shown to vary from 0.11 to 1.03. Some peat is lighter than water and will float, while other peat is heavier than water and will sink.

The following table has been compiled from figures given by Thurston.* It compares the weight, density, and specific gravity of several types of peat fuel with coal.

TABLE 3.

Weight, Density, and Specific Gravity of Various Fuels.

Material	Wt. Per Cu. Ft. Pounds	Specific Gravity
Cut peat	13	0.50
Machine peat	21	0.95
Peat briquettes	56	1.12
Bituminous coal	60	1.30
Anthracite coal	63	1.15

Water Holding Properties.—Peat is largely composed of water. Its capacity to absorb and hold water is great. It may have as much as 95 per cent of water in its raw condition. This water is held mechanically. Only a small part of the water can be removed by pressure or by centrifugal processes, the structure of the plant remains

*Thurston. Elements of Engineering.

being such that the greatest pressure will not remove it. Peat containing 90 per cent of water can be freed of it by pressure down to 70 per cent., but no more. Drying, on the other hand, evaporates the greater part of the moisture including that contained in the cells and cavities of the peat material, and this is really the only effective means of removing the water. Drying may be done either by air and wind or by artificial means. Air and wind-drying will bring the moisture down to 20 or 25 per cent, but this moisture content varies from day to day and depends upon the amount of moisture in the air. This is due to the capacity which peat possesses of re-absorbing moisture after being once dried. Artificial drying will remove all the water from peat, leaving it in a water-free condition.

Upon being dried, peat shrinks greatly, and often cracks and crumbles. A ton of raw peat contains about 1,800 pounds of water and only 200 pounds of solid matter, and the contraction in volume, caused by drying, results in cracking and crumbling.

Chemical Properties

Some of the chemical constituents of peat have already been pointed out in the preceding pages. The organic and inorganic materials of which peat is made up have been mentioned briefly.

In addition to the cellulose ($C_6H_{10}O_5$) and lignin ($C_{35}H_{24}O_{20}$), peat contains a number of other chemical materials that are of interest. These are made up of carbon (C), oxygen (O), and hydrogen (H). Certain resins, fats, and waxes, and some substances containing nitrogen (N), are also present. Sulphur (S) is found in small quantities.

In the decomposition of vegetable material fungi, bacteria, and other organisms are active in altering the chemical composition of peat, but these changes are not well understood.

It is known that a number of substances of acid properties are contained in peat which sometimes impart acid properties to the peat. Among these may be mentioned substances grouped under the head of humus, like humic, ulmic, geic, crenic and pectic acids. These are derived from humin, ulmin,etc.

Bituminous and resinous compounds are found in peat, and chemical substances are formed from these upon distillation or conversion of peat into gas. Among these may be mentioned carbon dioxide (CO_2), oxygen (O), nitrogen (N), carbon monoxide (CO), methane (CH_4), several other hydrocarbons of the ethylene series, and hydrogen (H).

Then there are products derived from tar, among which are found ammonia, oils, paraffin, asphalt, creosote, alcohol, etc.

Further, materials contained in the ash represent another line of substances. Among these are potash, soda, lime, alumina, iron, sulphuric acid, chlorine, and phosphoric acid.

Some varieties of peat give an acid reaction, others are alkaline.

Combustion Characteristics

Light, fibrous, dry peat of good quality will ignite at a temperature of about 400° F. in air. It is easily kindled, the lighter, fibrous varieties igniting at the temperature stated, and burns with a red, smoky flame freely and quickly. The denser, blacker varieties of peat require a somewhat higher ignition temperature, burn slower, more sluggishly, and last longer. A peculiar, sharp, pungent, biting, and penetrating odor accompanies the burning of peat. Little smoke is produced; such as there is being gray or white in color. The resulting ash is light in weight, light in color, and powdery, and does not clinker or form slag. There is an absence of smoke, soot, dust and dirt. The heat produced is intense. Under suitable conditions of draft, dry peat of good quality will develop a temperature of over 4,000° F. upon combustion. Peat fuel is light, clean, and easily handled.

Composition and Calorific Values of Peat Compared with Other Fuels

Because of the fact that peat is principally used as a fuel, its relative rank among other fuels is of interest. The following tables give data which serve as a basis of comparison. A general idea of its physical and chemical properties may be obtained from a study of these tables.

Comparing some of the physical properties of several classes of peat with coal we have the following figures:

TABLE 4.

Physical Properties of Peat and Coal.*

Material	Weight per Cubic Foot as Piled. Lbs.	Relative Weight for Same Heating Value	Relative Bulk for Same Heating Value	Specific Gravity
Cut peat	13	2.99	14.36	0.50
Machine peat	21	2.45	2.56	0.95
Peat briquettes	56	2.04	2.14	1.12
Bituminous coal	60	1.36	1.43	1.30
Anthracite coal	63	1.00	1.00	1.45

*Carter, W. E. H. "Peat Fuel: Its Manufacture and Use." Report of the Bureau of Mines, Ottawa, Canada, 1903.

The following table gives an idea of the heating power and chemical composition of peat and other fuels.

TABLE 5.

Heating Power and Chemical Composition of Fuels.*

Combustible	C	H	O	N	S	Ash	B. T. U.† per Pound
Wood, air dried	40.4	4.90	32.70	0.90	....	1.20	6400
Peat	40.8	3.30	26.30	1.00	....	7.70	6800
Peat, air dried	46.1	4.60	23.60	1.00	....	1.50	7600
Lignite, American	50.1	3.90	13.70	0.90	1.50	13.20	10300
Lignite, Australian	64.3	4.20	10.00	1.00	0.60	10.00	11000
Coal, Welsh	83.78	4.79	4.15	0.98	1.43	4.91	15100
Coal, Newcastle	82.12	5.31	5.69	1.35	1.24	3.77	15200
Coal, Lancashire	77.90	5.32	9.53	1.30	1.44	4.88	14600
Coal, Scotch	78.53	5.61	9.69	1.00	1.11	4.03	14900
Coal, Big Muddy, Jackson County, Ills	69.90	5.26	8.35	1.33	2.02	6.90	12600
Coal, Johnson County Arkansas	83.74	4.52	0.54	1.50	1.60	6.63	14400
Coal, Block, Idaho	82.70	4.77	8.81	1.74	0.98	1.00	14000
Coal, Hocking Valley, Ohio	72.29	6.53	8.28	1.50	0.43	2.72	13400
Coal, coking, Pittsburg, Pa	79.81	5.98	4.80	1.50	1.35	6.48	14400
Coal, anthracite	91.50	3.50	2.60	....	....	....	15200
Coal, anthracite, Pennsylvania, buckwheat	81.32	....	....	....	0.67	10.96	12200
Petroleum, crude, from Baker, Russia	86.5	12.00	1.50	....	....	....	19800
Petroleum, heavy crude, from Pennsylvania	84.9	13.70	1.40	....	....	....	19200
Petroleum, common, from Virginia	85.3	13.90	0.80	....	....	....	18100

C means per cent of carbon contained in the combustible; H, the per cent of hydrogen; O, the per cent of oxygen; N, the per cent of nitrogen; and S, the per cent of sulphur.

*From "Steam Engines and Boilers," p. 236, by J. H. Kinealy.

†"B. T. U." is the abbreviation for "British Thermal Units." The British thermal unit is that amount of heat necessary to raise one pound of water one degree Fahrenheit.

Table 6, compiled from the works of Kent, Poole and others, compares the heating values of various fuels.

TABLE 6.

Heating Value of Fuels.*

Fuel	*British Thermal Units per Pound of Fuel*
Oil	19,000
Coke	14,300
Anthracite coal	14,600
Semi-anthracite coal	14,700
Semi-bituminous coal	15,500
Bituminous coal	14,400
Lignite	11,000
Peat	9,000
Wood (yellow pine)	9,153
Wood (ash)	8,480
Wood (oak)	8,316
Bagasse	3,000
Natural gas (per cu. ft. at atmospheric pressure)	1,000
Illuminating gas (per cu. ft. at atmospheric pressure)	600
Producer gas (per cu. ft. at atmospheric pressure)	150

For further comparisons of various fuels see "Gas and Fuel Analysis for Engineers," by A. H. Gill, Chapter VII.

*Spangler, Green and Marshall. "Elements of Engineering," p. 4.

The combustible contents of several fuels compare as follows:

TABLE 7.

Percentages of Combustible Contents of Fuels.*

Fuel	Fixed Carbon Per Cent of Combustible	Volatile Matter Per Cent of Combustible
Anthracite coal	100 to 92	0 to 8
Semi-anthracite coal	92 to 87	8 to 13
Semi-bituminous coal	87 to 75	13 to 25
Bituminous coal	75 to 50	25 to 50
Lignite	Below 50	Over 50
Peat†	37.8 to 23.4	62.2 to 76.6

†Based on the results of the Wisconsin Peat Survey in 1903. See Chapter VII.
*Babcock and Wilcox Boiler Co., "Steam." p. 52.

CHAPTER II.

THE PREPARATION AND USES OF PEAT.

Introduction

It is the purpose of this chapter to point out some of the methods, processes, and machinery which have been employed in Europe and elsewhere in efforts to utilize peat deposits.

Prolonged experiments in Europe have resulted in much progress and in many places the utilization of peat deposits is being carried on with commercial success. In the United States, however, there have been few commercially successful peat developments. Efforts along this line have been confined chiefly to the manufacture of peat into fuel, but since coal is still cheap and plentiful there is little incentive for experimental work in peat utilization.

A careful study of European progress along this line is of value in showing how far peat utilization has developed and what may be expected of peat.

Historical*

"The use of peat as fuel in Germany goes back beyond the historical period into the time of the semi-savage stage of the early tribes, and Pliny, the Roman naturalist, tells us that the Teutons on the borders of the North Sea dried and burned 'mud,' or, as we would call it now, peat. In Ireland, Great Britain, Russia, Scandinavia, parts of France and the Netherlands, there has not been a time within the historical period, when the use of peat for fuel has not been a general practice among the common people, who still cut it from the bog in the form of long rough bricks or 'sods,' drain and dry it on the surface of the bog in the sun and wind and stack it, much as the American farmer piles his cut wood.

"In Ireland and parts of Germany and Holland the use of peat is well nigh universal among the poorer people, and in other countries of Europe it is extensively used for cooking and other domestic purposes. This is due to several causes, among which are the scarcity and high prices of wood and coal, and the great abundance of peat bogs and the large aggregate area covered by them in the countries

*This matter is greatly condensed from a report by C. A. Davis, Geological Survey of Michigan. Annual Report, 1906, p. 311.

of northern Europe, Germany alone having an area of about 11,000 square miles of peat moors, while Great Britain has more than 3,000,000 acres, and Ireland an equal extent, or about one-seventh of its entire area covered by bogs. The most widespread use for domestic purposes was probably in the 18th century, after the forests were so depleted that wood was no longer easily obtainable by the common people, and before coal had come into use.

"While the general use of peat by the people for domestic purposes has gone on for century after century, there was little attempt to increase its efficiency as fuel, or to improve the methods of gathering it, except some simple attempts at compacting the coarser types by kneading with the feet, grinding in small mills, etc., until within a hundred years or so when various forms of machinery were introduced to assist in cutting the peat and getting it out from the bogs more quickly and less laboriously than by cutting it out by hand with a narrow spade or slayne, as it is called, and which is still the most common and perhaps the most efficient tool for the purpose.

"Much later, after the need for cheap and abundant fuel for use in generating steam for manufacturing purposes began to be felt, as the prices of wood and coal advanced, machines began to be built in Germany and other parts of Europe where peat was abundant, for the purposes of increasing the output, of reducing the bulk of the finished product, and at the same time of making it more clean to handle, more easy to transport, and more efficient as fuel. * * *

"Parallel with the development of these processes in Germany, have gone similar ones in England, Russia, Norway, Sweden, Austria and the Netherlands, but Germany has led the way, and it is there that the most modern and scientific methods and machinery for the manufacture of peat into efficient fuel have been worked out. In fact, there has been much labor and a great amount of capital used up in various unsuccessful processes of handling peat in Germany, and no better step could be taken by the would-be inventor of new and especially desirable processes of converting peat into first rate, cheap fuel, than to make a thorough study of the history of German inventions and experiments in this direction, for it would doubtless save him much time and trouble as well as much money and disappointment.

"In America, with its great stores of fuel, in the form of wood, and the various types of coal, widely distributed, cheap and abundant, the history of the use of peat is very brief. It was used in parts of New England by early settlers from peat-using stocks, and in the

region of Cape Cod and the adjacent islands in Massachusetts, where the original forests were poor and soon destroyed, the use of peat, taken from the numerous bogs of the region, * * * has been general and continues until the present time. In other parts of New England, its use was discontinued years ago. * * * It was not until the great coal miners' strike of 1902–03 created a widespread interest in the possibility of utilizing the extensive deposits of various kinds of peat known to exist in the northern parts of the United States, that the public took much notice of it.

"In Canada, the history is slightly different, though similar. There the deposits are more extensive than in most parts of the United States, are easily accessible and the land was settled from the more northern parts of Europe, and especially from Scotland, Ireland and Germany, by people who were used to gathering and using peat for fuel. These facts, taken in connection with remoteness from coal supplies, undoubtedly led to a more extensive and earlier use of peat for fuel than in this country, so that in the early sixties, there was a small output of machine made peat, and a little later, carbonized pressed peat, was placed on the market and tested by manufacturers and railroads. This was followed by a slow development of briquetting machinery, until several plants were established to make peat briquettes, none of which were successful in getting a good product from the process used, that of air-drying, grinding and pressing the peat, and after a season or two of attempts, were abandoned. The next series of attempts were made in the direction of pressing the peat after it had been dried by artificial heat, and in 1902 several establishments in Ontario were operating, and with more or less success, were supplying a local market with briquettes made by modifications of this process. * * *"

Preparation of Peat for Fuel

In general there are three methods of preparing peat for fuel and the peat thus prepared is known as

A. Cut Peat.
B. Pressed or Machine Peat.
C. Peat Briquettes.

Cut Peat

The simplest method of peat fuel preparation, and one which has been in use in Europe from ancient times down to the present, consists of cutting the peat out of the bog in the form of rectangular

blocks by means of special peat-spades or slaynes. Slaynes of various forms are used, but the most common form consists of a long, narrow-bladed spade having a short, sharp lug welded at right angles to the point of the blade. As fast as cut, the blocks are spread out upon the previously cleared surface of the bog in order that air and sunshine may dry them. During the drying process they are frequently turned, and when partially dry, are piled up in heaps or stacks for further drying and storage. From four to six weeks are required for the completion of the drying process and at the end of this time the peat retains from 20 to 10 per cent of moisture.

In working a bog the following procedure is usually followed: First, the bog is thoroughly drained. Next, a drying field of ample size is laid out, levelled and drained by cutting small ditches across it, about one foot wide and 30 to 60 feet apart. Finally, the bog is divided up into sections. Two men usually work a section. One of the men cuts peat and places it on the edge of the working trench, and the other man loads the peat onto wheelbarrows or trucks, transports it to the drying field and piles it up in proper manner for drying in the open air. On account of its porous nature and its moisture absorbing properties, peat becomes saturated with water in rainy weather. Often, therefore, the peat, when cut, is piled up in drying sheds. The tops of these are covered to protect the pile from rain but the sides are left open to admit the free access of air. The peat is also usually piled upon boards laid upon the ground to prevent the peat from absorbing moisture from below.

Machinery for the cutting of peat has also been devised and used in place of hand cutting. The use of machinery usually makes it possible to get out a greater volume of peat and increases the production.

Peat is worked up in these ways during the summer months so as to be ready for consumption during the winter months.

The physical characteristics of this form of peat fuel depend largely upon the quality and structure of the raw peat. The Swedish Peat Society found that a cubic yard of this material varies in weight between 288 and 396 pounds. It is porous, bulky, easily crumbled and broken. It burns freely and quickly but, on account of its property of crumbling easily, there is considerable waste in handling and firing. However, since little mechanical equipment is required for manufacturing cut peat, its cost of production is small.

It would seem that this method of peat fuel preparation is not suited to American conditions because it cannot be carried on effi-

ciently on a large scale. Individual owners of small peat deposits, however, might employ it to advantage in utilizing their deposits for home consumption in districts where peat is cheap and abundant while the price of other fuels is high.

Machine Peat

Cut peat, when prepared, is often variable in texture and quality and crumbles easily. For commercial purposes a fuel more durable and uniform in quality is desirable. Machine peat is a product in which the attempt has been made to overcome some of the shortcomings of cut peat.

By the term "machine peat" is ordinarily meant peat which, after being cut from the bog, first undergoes special treatment, with or without the addition of water, and is then moulded by hand or by machinery into blocks of suitable shape. These blocks are stacked up and dried by the air and sunshine. Crude peat, upon being dug, is ground up into pulp while in its wet condition, and is then cut, or moulded, or pressed into blocks. After being formed, the rectangular blocks or bricks are exposed to the air and are allowed to dry under drying sheds for a period of time varying from six to eight weeks. By the use of artificial heat this time may be shortened, but the natural, air-drying process has proved more successful than any artificial methods of drying.

As a result of the grinding and maceration processes, the escape of moisture from the peat is greatly aided. The resulting bricks contain less moisture and shrink to about two-thirds of their original size. Machine peat withstands exposure to the weather much better than cut peat, has a denser, harder texture, crumbles less easily and can be transported without breaking. The grinding and macerating process seems to impart a self-binding property which makes the blocks almost waterproof when dry. This treatment breaks up and destroys the cellular structure of the peat and develops certain insoluble substances which, when dry, bind the mass and give it the more desirable properties of durability, transportability, uniformity and compactness. Air-dried machine peat contains from 15 to 25 per cent of water. (See Plates II, III, and XIX.)

One of the simplest early processes which utilized this idea employed men or animals to thoroughly mix and knead the raw peat, to which water was added after digging, into a pulp by trampling upon it. When properly mixed, the pulp was formed into blocks by pouring it into moulds to dry. Such a manual process, however, would

seem too crude to be used with success in preparing peat fuel on a large scale and, therefore, would hardly be expected to come into use except for small and isolated plants.

The production of peat fuel of this kind upon a scale of considerable magnitude involves the substitution of machinery for manual methods.

The principal device used in the machine peat process is the peat machine. It consists, in its simplest form, of a device for thoroughly cutting, tearing, grinding, macerating, and mixing the raw peat which is taken from the bog. All of the most approved forms of peat mills for machining peat operate on the same principle. In structure they resemble the brick makers' "pug-mill" and, in fact, ordinary clay or brick pug mills have often been used for machining peat. They consist of a hollow iron cylinder, inside of which is a set of knives or cutters, which by revolving, grind, knead and mix the crude peat thoroughly. Screw rollers force the material past the cutters and out through rectangular openings so that the mixed material issues in the shape of a rectangular plug. This plug is then cut into bricks or blocks of any desired size. Plate XIX gives an idea of such a peat machine.

These machines are built in a variety of sizes and shapes ranging from those operated by horse power and having a capacity of three tons of air-dried fuel per working day to those requiring prime movers of considerable size and capable of turning out fifty tons in ten hours.

After the peat has been machined into blocks these are laid upon wooden frames called "palletts" and stored under air-drying sheds until they contain no more than from 15 to 25 per cent. moisture. In this condition it is ready for market.

A great variety of digging and conveying machinery has been developed to handle the peat both before and after machining it into blocks.

Peat Briquettes

In preparing peat fuel in the form of briquettes, the method described below is followed. It resembles somewhat the methods used in briquetting lignite and the poorer grades of coal.

The peat is first dug from the marsh and spread by mechanical digging and conveying devices into thin layers, and finally allowed to air-dry until 30 or 40 per cent of moisture remains. Next, the air-dried peat is thoroughly disintegrated and broken up with a view to liberating more moisture. It is then artificially dried in a drier until

its moisture content has been reduced to about 15 per cent. Following this treatment it is usually stored in hoppers until ready for the briquetting press. In the press, a plunger, working in a tube or die, exerts a pressure of from 15,000 to 30,000 pounds per square inch upon the peat which then emerges from the press in compact briquettes resembling coal.

A description of the briquetting machines used at the Whitewater, Wisconsin, peat plant is given on page 217.

The essential part of the press consists of a tube and plunger with a device for feeding the peat. For a simple form see Figure 2, which illustrates the principle embodied in some of the European briquetting presses. The plunger P which is driven by a crank or cam and

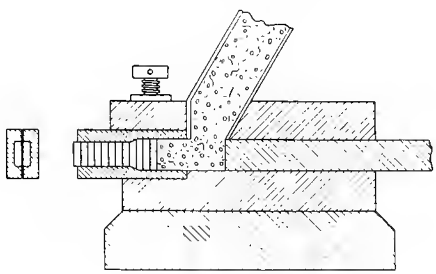


FIG. 2. SECTION OF BRIQUETTE PRESS

connecting rod, either directly connected to a prime mover, or by belting, operates in a die-block D. This die consists of an open tube of steel or cast iron and has a slightly larger cross-section nearest the hopper F. When the plunger is moved forward the material fed in by the feeding apparatus is pressed into a briquette. When the plunger is moved backward a new portion of raw material is fed in, and this is compressed into a briquette when the plunger moves forward again. The briquettes previously made are moved forward each time a distance equal to the thickness of the new briquette, and when passing from the wider section of the die to the narrower section they are again submitted to pressure. The briquettes issue at B in the form of a plug, several briquettes usually sticking together. But they separate easily into individual briquettes when cool.

In this process heat is developed by the friction and pressure in the die and this is often so great that the die must be water jacketed and the heat carried away. But a portion of this heat is utilized in setting free some of the tarry constituents of the peat, which bind

the mass together and impart a black, glossy finish to the surface of the briquettes. Briquettes are made in a variety of shapes and sizes which depend upon the cross-section of the die and plunger. They may be oval, disk-shaped, cylindrical, square, etc. They resemble coal in color and texture.

Several processes used in connection with the briquetting of peat have been developed which have for their object the treatment of the peat in such a way that the moisture may be removed more readily. But these have not proven that they add anything to the economy of operation.

Among these may be mentioned an electric process for drying peat. A current of electricity is passed through the wet peat, the object of this treatment being to break up the cell walls and fibres of the vegetable matter causing them to give up the water they hold. After being thus electrically treated the peat is passed through presses for squeezing out the water. But this process seems to possess little merit.

Another of these processes is that devised by Ekenberg. The wet carbonizing process, as it is called, for preparing peat for briquetting involves the carbonization or coking of the peat by heating it in its raw state under pressure. It is superheated in closed retorts to a temperature of about 300° F. When treated in this way peat seems to lose its gelatinous structure and becomes amorphous. It takes on a black color, and is altered so that the water can be pressed from it. The residue remaining after the water has been removed is artificially dried and then briquetted.

Peat Powder

If peat, which has been taken from the bog and allowed to disintegrate by lying on the surface of the bog during the winter, be gathered, dried artificially and pulverized, a dark-colored, non-absorbent powder will result. The name "peat powder" has been applied to this product. It may be used in very much the same way that sawdust and powdered coal have been used.

When this powder is burned in specially constructed burners using a blast of air, it acts very much like a gas, on account of the intimate mixture of powdered peat and air which may be obtained. The air supply can be regulated so as to approach that theoretically required for perfect combustion, and complete, smokeless combustion results. The temperature of the flame is easily regulated, and temperatures sufficiently great for melting glass, iron, steel and for other metallurgical operations, can be obtained.

Peat Coke and Charcoal

Peat, instead of being used for fuel as peat, may be converted into coke and charcoal and the coke or charcoal so obtained used in operations where such material is employed.

The oldest method of coking peat consists of cutting the air-dried material into lengths of about 2 feet as it issues from the peat machine. These are set on end, in heaps of about 20 feet in diameter by 10 feet in height. The pile is then covered by a layer of dry grass and a layer of fine, broken, coke or charcoal, and coked in the manner of coking wood. This operation requires about two weeks' time. It is not a very efficient commercial method.

The next step in the development of the peat coking methods is that in which the coking is done in ovens and retorts. This method has some advantages over the "coking in heaps" method such as:

1. It requires less attendance.
2. The process is independent of weather conditions.
3. Some of the by-products can be saved.

By the oven and retort methods, by-products similar to those obtained in making charcoal by the destructive distillation of wood are obtained. These by-products may be classified into two groups as follows:

(a) Methyl or wood alcohol,
Ammonia or ammonia sulphate,
Acetic acid or acetate of lime.

(b) Illuminating and lubricating oils,
Paraffine wax,
Phenol (creosote oil and carbolic acid),
Asphalt.

The former (a) are derived from the tar water and lighter distillates, while the latter (b) are obtained from the tar.

Perhaps the most successful and fully developed retort method for making peat coke and which seems to give promise of commercial development is that known as the Ziegler process. See Fig. 3. A description of this process as given by Nystrom* is as follows:

"Each unit consists of two vertical retorts about 40 feet in height with elliptical cross-sections. The lower half is built of fire-bricks, and the upper one of cast-iron with a thin outside lining of fire-bricks. Outside of these walls is another fire-brick shell, leaving an air-space between, which is by means of walls divided into fire flues. The

*Nystrom, E. Peat and Lignite. Bull. Canada Dept. of Mines. Ottawa, Canada, 1908, p. 176.

PEAT FUEL, BROKEN.

PEAT COKE, BROKEN.

Cut loaned by Geological Survey of Michigan.

whole oven is then protected by a wall of common bricks. The retorts rest upon a cast-iron foundation, and end in a hopper (a) provided with two openings for the drawing off of the peat coke. Each

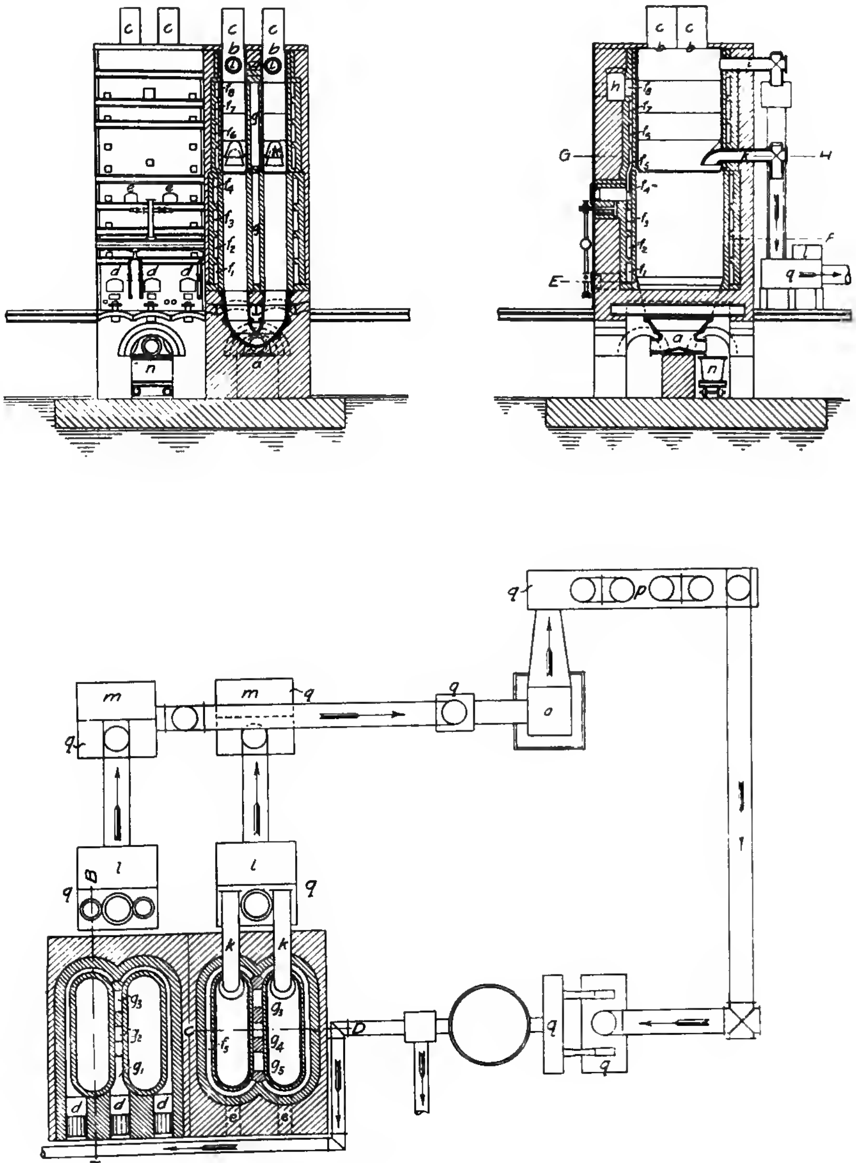


FIG. 3. ZIEGLER'S PEAT COKING RETORTS

of the retorts is closed on top by cast-iron covers carrying the feed boxes (c). The openings through which the peat is fed and the coke is drawn off are air tight. When the oven is started, extra fuel must be used until the coking process is under way. For this purpose the oven is provided with three lower fire-boxes (d) and two upper ones (e). The combustion gases pass through the fire flues (f) and (g), and from there to the collecting flue (h). They are later either used for drying of the peat in specially constructed drying chambers, or escape through the chimney. Each zone of the oven (each fire place) is provided with a peep hole on the front and rear side for the purpose of watching and taking the temperature. In the lower fire flues, the temperature reaches some 1,000° Centigrade, and in the upper ones, 600°, 500°, and 400° respectively. The highest temperature in the retorts themselves reaches some 600° Centigrade. The heat contained in the gases (200° to 300° Centigrade) resulting from the dry distillation of the peat, and collected through the pipes (i) and (k) is used for drying the ammonium sulphate and acetate lime (part of the by-products) in the vessels (l) and (m).

"The retorts are charged with peat, which, if good coke especially for metallurgical purposes is desired, must contain little ash, be well pulped, and not contain more than 20 to 25 per cent moisture. At first, extra fuel is used, but after 48 hours sufficient non-condensable gases are given off so that peat firing can be discontinued and the gases ignited. The air necessary for the combustion is previously heated by passing it around the cast iron hoppers forming the bottom of the retorts, and at the same time cooling off the coke in same.

"When the process is in continuous operation, the coke is hourly drawn off from the hoppers into air-tight steel cars (n) in which it must be left until thoroughly cooled. After each withdrawal of coke, fresh peat bricks are charged through the feed boxes (c). The operation thus becomes a continuous one.

"The water vapors and gases generated are drawn off by an exhaust fan (o) and driven through an air cooled pipe condenser (p) where the tar and tar water condense. The non-condensable gases are by means of another fan forced back to the oven where they are used for heating the retorts. At a plant with a number of ovens more gas is obtained than is required for this purpose, and in such cases the excess is used under the boilers or in gas engines."

Peat coke obtained from the Zeigler ovens is hard and strong and gives the following analysis:

Analysis of Peat Coke from Ziegler Oven.

Carbon	87.8%
Hydrogen	2.0%
Nitrogen	1.3%
Oxygen	5.5%
Sulphur	0.3%
Ash	3.2%
Calorific value:	
Calories per kg	7,889 to 7,805
B. T. U.	14,200 to 14,049

The Ziegler ovens are also used for the manufacture of "peat half coke," which is partially coked peat from which all of the hydrocarbons have not been extracted. Half coke made in Ziegler retorts gave the following analysis:

Analysis of Half Coke from Ziegler Oven.

Carbon	73.89%
Hydrogen	3.59%
Nitrogen	1.19%
Oxygen	14.52%
Sulphur	0.29%
Ash	2.50%
Moisture (at 105°C)	3.80%
Calorific value:	
Calories per k. g.	6,700
B. T. U.	12,060

It is reported that one pound of peat half coke under a stationary boiler evaporated 6.63 pounds of water, and under a locomotive boiler 5.76 pounds. In the stationary boiler the following evaporations were obtained with the fuels indicated:

1 lb. wood	produced 3.24 lbs. steam
1 lb. Russian coal (Don)	produced 6.67 lbs. steam
1 lb. briquetted coal	produced 7.10 lbs. steam
1 lb. peat half coke	produced 6.63 lbs. steam

By means of auxiliary distilling plants alcohol, ammonia, acetic acid, paraffine, creosote, and asphalt are recovered from the tar and tarry water.

The peat coke thus produced is suitable for use in metallurgical operations, and for the manufacture of carbons and electrodes.

Gas from Peat by Destructive Distillation

Whenever any fuel, containing hydrocarbons, is heated in a closed retort from which air or oxygen is excluded it is broken up into a series of simpler chemical compounds. This process is known as destructive distillation. During the process of heating gases are liberated and these carry over with them other materials like water, tar, organic acids, ammonia, alcohol, creosote, etc. These are afterwards removed from the gas by suitable washing, scrubbing, and purifying devices. Coke is left behind as residue.

Sometimes destructive distillation in retorts is carried on for the purpose of generating gas, the coke and chemicals being regarded as by-products. Again, coke and the chemicals are the principal products, while the gases are the by-products.

The following table shows the composition and heating value of such gas:

TABLE 8.

GAS FROM PEAT BY DESTRUCTIVE DISTILLATION

<table>
<tr><th>Constitutent Gas</th><th>per cent by volume</th><th>per cent by volume</th><th>per cent by volume</th><th>per cent by volume</th><th>per cent by volume</th></tr>
<tr><td>Methane (CH_4)</td><td>29.4</td><td>14.8</td><td rowspan="2">12.4</td><td>9.4</td><td>17.9</td></tr>
<tr><td>Heavy hydrocarbons</td><td>2.1</td><td>1.0</td><td>3.3</td><td>4.1</td></tr>
<tr><td>Hydrogen (H_2)</td><td>26.8</td><td>23.6</td><td>28.6</td><td>15.2</td><td>21.3</td></tr>
<tr><td>Carbon mon-oxide (CO)</td><td>8.2</td><td>8.6</td><td>20.4</td><td>9.5</td><td>14.6</td></tr>
<tr><td>Carbon dioxide (CO_2)</td><td>32.7</td><td>27.4</td><td>15.5</td><td>30.7</td><td>27.0</td></tr>
<tr><td>Nitrogen (N)</td><td>0.7</td><td>22.5</td><td>21.9</td><td>26.0</td><td>10.3</td></tr>
<tr><td>Oxygen (O)</td><td>0.1</td><td>2.2</td><td>1.1</td><td>6.0</td><td>4.8</td></tr>
<tr><td>B. T. U. per cubic foot</td><td>475</td><td>322</td><td>.....</td><td>.....</td><td>380</td></tr>
<tr><td>Authority</td><td>A</td><td>B</td><td>C</td><td>D</td><td>D</td></tr>
</table>

Authorities.

A. See this bulletin, p. 194. From Benedict, W. J., and Saradakis, F. J., "An Analysis of the Products of Distillation of Wisconsin Peat." Thesis University of Wisconsin, 1904.

B. From a report by a commission appointed by the Prussian Govt. to investigate the Oldenburg plant, Oldenburg, Germany, 1901. See Nystrom, E., Peat and Lignite in Europe. Canada Dept. of Mines, 1907, p. 180.

C. Report of Plant at Bauerberg Germany., See Davis, C. A., Bull. 16, U. S. Bureau of Mines, 1911, p. 135.

D. See this bulletin, p. 202. From Leasman, E. L., "Wisconsin Peat and its By-Products." Thesis, University of Wisconsin, 1907.

These gases are inflammable and produce some heat and a small amount of light. But the manufacture of peat gas by the retort method, that is by destructive distillation, has met with little commercial success principally because it has little heating value, low luminosity, and contains high percentages of carbon-dioxide and nitrogen. It is sometimes used for heating the retorts in coking and by-product recovery plants of the Ziegler and similar types.

Producer Gas

A method of gas generation applicable to all sorts of fuels, and especially adapted to low grade fuels, is that in which the fuel is gasified in a "producer." Gas made by this process is known as "producer gas." Because of the fact that certain practical experiments have been made along the line of converting peat into producer gas which are of recent date, and further, because this method gives promise of commercial success in the utilization of peat, the process is described somewhat in detail.

Producer gas is entirely different from illuminating gas which is formed either by the distillation of bituminous coal in a closed retort or by enriching water gas formed by the decomposition of steam by incandescent carbon. By "producer gas" is generally meant gas formed by the partial combustion of fuel in a suitable apparatus. Partial combustion in producer work means the incomplete oxidation of the combustible components of the fuel, resulting in its complete gasification. Some of the combustible components of the gas evolved are not fully oxidized, while others are not oxidized at all, and the oxidation of the gases is carried on by the burning in a gas engine or furnace.

The Gas Producer

"A gas producer, as a trade term, is an apparatus for generating a combustible gas by the incomplete combustion of a solid fuel. It is thus distinguished from the retort of the illuminating gas process, or other apparatus of production by volatilization, vaporization, enrichment, etc., using a solid or a liquid fuel.*" It is an apparatus for converting solid fuel into a combustible gas, and this is usually a mixture of varying proportions of carbon monoxide, hydrogen, gaseous hydrocarbons, oxygen, carbon-dioxide, and nitrogen. Of these, carbon monoxide, hydrogen, and the hydrocarbons are combustible, while carbon-dioxide and nitrogen are diluents. By means of pro-

*Wood R. D. & Co., Gas Producers and Producer Gas Power Plants, 1909, p. 32.

ducers any carbonaceous fuel like anthracite and bituminous coals, lignite, peat, wood, and oil may be converted into gas. Fig. 4 gives an idea of the construction of a gas producer.

The producer is a vertical iron vessel, either cylindrical or rectangular in shape, lined with fire brick. At its top is a fuel charging device by means of which the fuel may be fed into the producer

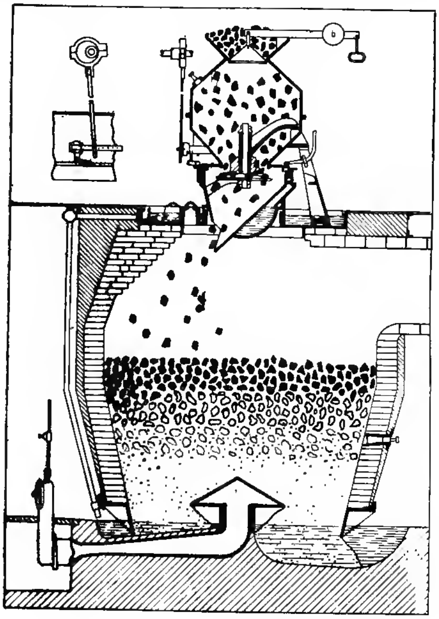


FIG. 4. A GAS PRODUCER

without admitting air. At the bottom is a grate for supporting the fuel bed. This grate may be either stationary or arranged to automatically shake the ash and clinker. At the upper end, and usually on the side, is a gas outlet, and at the bottom is an air inlet. At different points on the sides are holes for poking the contents, inspecting the condition of the fuel bed, etc. Usually, the bottom is provided with a water seal to prevent the entrance of air except through the proper openings.

Types of Producers.

Gas producers are made in three distinct types:

1. Suction Producers.
2. Pressure Producers.
3. Down Draft Producers.

1. Suction producers supply gas direct to the engine for which they furnish gas. The suction created by the forward travel of the engine piston is used to draw the air and steam into the producer, and gas is thus generated as slowly or rapidly as the load on the engine requires. These producers are particularly adapted for the use of anthracite, charcoal, and other non-bituminous fuels. Tar developed from bituminous fuels is carried over into the engine and causes difficulty from clogging of valves and other working parts.

2. Pressure producers differ from suction producers principally in the method of supplying air and steam to the fuel, these being forced in by outside pressure. The gas is formed under pressure and may be stored in gas holders until needed. This permits of better cleansing methods, and the gas may be used for other purposes besides being converted directly into power in engines. Such other uses are in furnaces and heating, lime burning, ore roasting, forge work, cement burning, boiler firing, etc. Fuels containing a considerable amount of hydrocarbon or bituminous matter can thus be utilized.

3. In the down draft type of producer, the tars and other distillates are destroyed and converted into permanent gases by drawing them from the top of the producer and passing them through the fuel bed. They are converted into simple, permanent gases through contact with the incandescent carbon. The most successful peat producers have been built on this plan as the difficulty of valve trouble from tars being carried over into the engine is almost entirely overcome where this type of producer is used.*

Auxiliary Apparatus.

Producer gas made as described above contains impurities in the form of tar, dust, etc., and it is therefore necessary to wash, scrub, and purify it with suitable washers, scrubbers, and purifying materials.

Chemistry of Producer Gas Formation.

Assuming, for purposes of clearness, that the producer is in operation and that the fuel is carbon, the inside of the producer and the actions going on there may be described thus.

There will be several zones as follows:—

Zone 1 is filled with producer gas of the composition shown in the accompanying tables.

*Haanel, B. F. The Utilization of Peat Fuel for the Production of Power. Bull. 154, Canada Dept. of Mines, Ottawa, 1912.

Zone 2 contains fresh fuel, recently fed, from which volatile matters are being driven off or distilled as a result of the heat below.

Zone 3 is a zone of incandescent carbon or coke from which the volatile matters have already been driven.

Zone 4 is the zone of complete combustion and highest temperature.

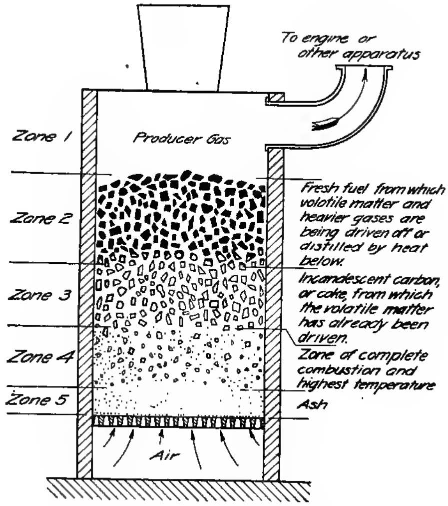


FIG. 5. SHOWING THE APPROXIMATE CONDITION OF THE FUEL BED IN GAS PRODUCERS

Zone 5 contains ash and residue.

It may be seen that the fuel bed ranges from a bed of newly fed fuel at the top to ashes at the bottom, with fuel in intermediate stages of carbonization, gasification, and temperature lying between. Air and steam enter through the grates at the bottom, or through a nozzle at the bottom.

Fuel engineers and chemists have not yet completely determined what actually takes place within the producer. It is rather a complicated process involving a series of chemical changes and reactions. The basic chemical elements upon which the reactions depend are the carbon in the fuel and the oxygen in the air supply. The net result is the formation of producer gas in Zone 1.

In the zone of complete combustion (zone 4) carbon dioxide is formed in accordance with the equation.

$$C_2+2O_2=2CO_2$$

from the carbon contained in the fuel and from the oxygen supplied

by the entering air. The nitrogen of the air is inert and does not enter into the reactions. It goes on through the producer and is found in the producer gas, but it has no fuel value and acts simply as a diluent and cooling agent.

The carbon dioxide formed in zone 4, upon reaching zone 3, is decomposed by the incandescent coke and gives up part of its oxygen. This liberated oxygen then immediately combines with the incandescent carbon so that the net result is the production of carbon-monoxide thus

$$2CO_2 + C_2 = 4CO.$$

Where fuels containing pure carbon and ash, like coke and charcoal are used, the above represents the producer process of making gas. The residue is ash. But other forms of fuel containing hydrocarbons are used for fuel and in gasifying these in producers, steam is introduced through the grates to supply additional oxygen. In passing through the incandescent portion of the fuel bed, the steam is broken up and unites with the fuel thus:

$$C_2 + H_2O + CO_2 + xN = 3CO + H_2 + xN.$$

In addition, due to the heating of the fuel in zone 2 by the hot gases and incandescent fuel of zones 3 and 4, a destructive distillation process goes on. And as a result hydrocarbons are driven off as small quantities of CH_4 (methane or marsh gas) and C_2H_4 (ethylene or olefiant gas).

Thus three gasification processes go on in the producer:—

1. The formation of air gas.
2. The formation of water gas.
3. The liberation of hydrocarbon vapors and gases.

Quality of Producer Gas From Peat

The chemical composition and heating value of various kinds of commercial gases are given in table 9. Producer gas from different sources is shown. This table was taken from Bulletin 16, U. S. G. S. p. 148 with the exception of the data on Canadian and Wisconsin peat. These were added from the other sources indicated. From this table it appears that producer gas made from peat compares favorably with producer gas made from other fuels.

TABLE 9

COMPOSITION AND HEATING VALUE OF COMMERCIAL GASES AND PEAT GAS

Character of Gas	H_2	CH_4	C_2H_4	N_2	CO	O_2	CO_2	B. T. U. Per Cu. Ft.	Authority
Natural Gas (Pittsburgh)	3.0	92.0	3.0	2.0	....	....	....	978.0	
Oil Gas	32.0	48.0	16.5	3.0	....	.5	....	846.0	
Coal illuminating gas	46.0	40.0	5.0	2.0	6.0	.5	.5	646.0	
Coke oven gas	50.0	36.0	4.0	2.0	6.0	.5	1.5	603.0	Wyer, S. S. Treatise on Producer Gas and Gas Producers, p. 50.
Carburetted water gas	40.0	25.0	8.5	4.0	19.0	.5	3.0	575.0	
Water gas	48.0	2.0	....	5.5	38.0	.5	6.0	295.0	
Producer gas from Anthracite coal	20.0	....	....	49.5	25.0	.5	5.0	144.0	
Coke	11.1	0.2	0.1	57.5	21.9	....	9.2	102.6	U. S. G. S Bull. 332, p. 289.
Bituminous coal	15.6	1.9	0.4	52.0	20.9	.0	9.2	156.1	U. S. G. S. Bull. 332, p. 452.
Bituminous coal	15.0	2.2	0.5	53.2	19.2	....	9.9	151.0	U. S. G. S. Bull. 332, p. 28.
Lignite	15.4	2.6	0.4	51.8	18.8	.2	10.8	154.8	U. S. G. S. Bull. 332, p. 28.
Florida peat	18.5	2.2	0.4	45.5	21.0	....	12.4	175.2	U. S. G. S. Bull. 332, p. 28.
Massachusetts peat	13.9	2.1	....	51.0	22.5	....	10.5	166.1	U. S. G. S. Bull. 290, p. 133.
North Carolina peat	10.2	0.4	.06	60.8	16.9	.4	10.9	109.7	U. S. G. S. Pittsburgh plant. Down draft producer.
Swedish peat	8.5	4.4	.5	53.7	26.0	....	6.9	....	Kerr, W. A., Peat and Its Products
Swedish peat	6.3	5.6	.9	57.6	10.0	.5	9.7	132.0	Nystrom, E., Peat and Lignite in Europe, p. 222.
Canadian peat	10.2	2.4	0.5	57.9	17.7	.5	10.8	123.0	Haanel, B. F., Bull. 154, Canada Dept. of Mines. Ottawa, 1912.
Canadian peat	10.0	2.1	0.4	56.3	22.4	.3	8.5	129.0	Down draft producer.
Wisconsin peat	18.07	6.23	0.8	51.00	17.9	....	6.0	199.6	Cheney, S. W. and Moorehouse, L. B., Thesis, Univ. of Wis. 1904
Wisconsin peat	20.39	3.22	0.7	53.69	20.7	....	1.3	182.8	
Blast furnace gas	1.0	....	....	60.0	27.5	....	11.5	91.0	Wyer, S. S., Treatise on Producer Gas and Gas Producers.

Economic Results.

A few figures showing the amount of peat fuel required to produce a unit of energy are available and are given below.

TABLE 10

Peat Required to Produce a Unit of Power.

Economic Results

Peat from	Halifax Massachusetts 1	Orlando Florida 2	Alfred Ontario 3	Farnham Quebec 4	Lindsay Ontario 5
Average electrical horse power	200.0	205.0	47.3	36.3	51.9
Dry peat consumed in producer					
Lbs. Per E. H. P. hr	1.81	2.39			
Lbs. Per B. H. P. hr	1.54	2.03	1.60	1.91	1.78
Lbs. Per K. W. hr			2.44	2.91	

Tests 1 and 2 reported in Bulletin No. 290, U. S. G. S. 1906.
Tests 3, 4 and 5 reported in Bulletin No. 154, Canada Dept. of Mines, 1912.

By-Product Recovery Producers.

Ziegler, Mond, Frank and Caro, and Woltereck, have developed processes of by-product recovery from producers and retorts resembling producers. The principal by-product sought is an ammonium-sulphate and this is used in the manufacture of fertilizers for agricultural purposes.

Other Uses of Peat.

In Europe peat has been put to a variety of uses aside from its use for fuel or fuel manufacture. Considerable experimenting has been done in an effort to replace materials, now used in a number of processes, with peat because of the scarcity and cost of those materials and the abundance and cheapness of raw peat. Some of these uses are pointed out in the following pages.

Chemical By-Products.—It was pointed out in the sections devoted to peat coke and the gasification of peat, that several chemical by-products were developed. Acetic acid and acetates, wood alcohol,

formaldehyde, ammonia and ammonium compounds, phenol and creosote compounds, tar, oils, paraffin wax, and asphaltum are some of the products derived.

Alcohol.—Ethyl or grain alcohol has been made from peat by breaking down the cellulose, of which peat is largely composed, into sugar and then converting the sugar into alcohol by fermentation.

Ammonium Compounds.—Mond, Frank and Caro, and Woltereck experimented with processes of producer gas generation whereby a considerable portion of ammonium sulphate is obtained. The ammonium sulphate so recovered is used in the manufacture of fertilizing materials. The methods employed by these experimenters differ but slightly from each other. For a further discussion of these processes see the section devoted to producer gas.

Nitrates.—By treating a culture bed of peat with a dilute solution of ammonium sulphate and inoculating the peat with cultures of nitrifying organisms, nitrates are obtained which have been used for agricultural purposes.

Paper.—On account of the fibrous nature of some forms of peat it has been used to a limited extent for the production of paper and pulp. On account of the variable structure, small amount, and inferiority of the fibres, little success has been met with in producing the better grades of paper. But cardboard, suitable for boxes and containers, has been made and used and seems to serve the purpose for which it is intended. Some of the coarser grades of wrapping paper have been made from peat. Peat has also been manufactured into building and roofing paper. But even in the manufacture of cardboard it has been found necessary to mix peat fibres with wood pulp in about the proportion of 25% peat and 75% wood pulp to produce a satisfactory material. Peat paper mills have been operated intermittently but cannot be said to be upon a commercial basis as yet.

Woven Fabrics.—Some of the stronger peat fibres have been treated to make them pliable and then woven into fabrics, principally cloth suitable for blankets for horses and other live stock. Finer grades of cloth have been made from the yarn made from bog cotton fibres, which are said to be soft and nice when new, but they do not wear well.

Artificial Wood.—Fibrous peat has also been utilized by manufacturing it into sheets, blocks and fibre board for structural purposes. It can be used much like wooden boards and is used in place of plaster for finishing materials. It is strong and light,

almost waterproof, and is a non-conductor of sound and heat. Peat pulp has also been made into boxes, barrels and pails.

Mattresses and Sanitary Appliances.—Mossy peat material which has been cleaned has been made into mattresses. Such mattresses are reported to be especially useful in hospitals because of their light weight and softness, and particularly because of their absorbent, deodorizing, and antiseptic properties.

Moss Litter and Mull.—Fibrous peat, when prepared by the simple process of gathering, drying, cleaning and baling, has been used in Europe as bedding for stock. Its capacity to absorb large amounts of moisture, its deodorizing properties and its springiness make it especially desirable for litter in stock and dairy barns.

The mull or finer peat material, which has been separated from the fibrous portion, is used as an absorbent and deodorizer in place of more expensive chemicals for outhouses, closets, cesspools, etc. on farms.

Packing Material.—Fibrous or mossy peat is also used considerably as packing material for fragile or perishable articles and has been applied to such things as eggs and fruits for cold storage. The mossy portion, in particular, is much used by florists for packing and preserving plants and flowers during shipment.

Fertilizer Filler.—Fibrous peat is often used as the medium of carrying soil fertilizing materials such as animal wastes, nitrogenous materials, ammonia, etc. Dried and ground peat of the less fibrous variety is used for this purpose also.

Dye Stuffs.—The brown coloring matter contained in peat has been extracted and converted into a rich brown dye that is reported to be durable and permanent.

Tanning Materials.—Tannic acid, tannin and related substances, have been obtained from peat and these are suitable for tanning hides.

Medicinal Properties.—In some parts of Europe peat mud is used for giving mud baths in treating gout, rheumatism, neurotic and muscular pains, chronic stiffness of the joints, sciatica, nervous disorders, etc. The warmed mud in which patients are immersed is prepared for use by kneading it with mineral waters and charging it with carbonic acid and heating. At some of the baths the peat is naturally saturated with mineral matters.

Peat in Agriculture.

Peat has been used to some extent in connection with agricultural operations. But such use has not been extensive.

Soil for Crops.—Peat bogs or marshes have been drained in an effort to reclaim these areas and use the soil for raising crops. But on account of the variable composition of peaty and mucky soils it is difficult to determine what crops may best be raised upon them. In general, it may be said that some peat deposits, when drained, furnish good soil for grass and hay, and for certain trucks like onions, celery, cabbage, lettuce and other vegetables. Carrots, parsnip, beet, radish, potato, strawberry, lupine, buckwheat, spinach, turnip, peppermint, timothy hay and alsike clover are reported as suitable for growing on peat lands. High-bush blueberry and cranberry crops are raised on these lands also.

Crops raised on peat soil must be such as can stand cold nights and early frost. The low situations in which peat deposits occur, subjects them to unseasonable frosts during cold nights in the summer time.

Peat soils usually do not contain much plant food, are generally unproductive, and need to be enriched. Some sort of chemical soil treatment is required before they can be made productive. The brown-fibrous deposits are of the least value for crops, while the black, thoroughly decomposed types seem to be the most fertile. Some peat soils contain organic acids, humus acid, ulmic acid, and tannic acid, all of which are more or less poisonous, undesirable, and harmful to certain crops. Mineral salts, like sulphate of iron, bog iron, magnesium carbonate, may be present and are likely to be injurious constituents. On account of these impurities, peat soils usually have to be chemically treated before they are suitable for crop raising.

Certain types of peat deposit, on account of their acidity, are extremely valuable for cranberry culture and are used for this purpose with much profit.

Fertilizer.—Farmers sometimes use peat as an auxiliary fertilizing material, most often by composting it with stable or barnyard manure, but sometimes by applying it directly to the land.

Absorbent and Disinfectant.—Air-dried peat, both of the fibrous and powdered varieties, is quite useful as an absorbent of the nitrogenous liquids and gases from stables and barnyards. It acts as an

absorbent, deodorizer, and disinfectant and is often used in place of lime, ashes and other disinfectants used about the farm.

Bedding for Stock.—Peat has been used, when air-dried and free from sticks and lumps, for live stock bedding. Beds of this material last a long time, are soft and spongy, and are absorbent and odor-destroying.

Stock Food.—Condimental stock food has been prepared from peat by mixing it with molasses from sugar beet factories. The molasses is a food but, on account of its being a sticky liquid, cannot be fed to stock easily in its natural form. Peat is added to make it less sticky. Its value as a stock food is doubtful.

Packing Material.—As packing for eggs and vegetables placed in storage bins, pits, cellars, etc., air-dried peat has found some use. Because of its heat-insulating, absorptive and sterilizing properties, peat has some value in preserving such farm products.

Peat Ashes.—Peat ashes have been used to spread over fields in the belief that the phosphoric acid and potash in them would benefit the soil, but these chemicals are present only in small quantities in peat ash and its use in this way is of doubtful value, if not entirely worthless.

Considerations Relating To The Commercial Development of Peat Deposits.

The material contained in the foregoing pages has pointed out what peat is, how it may be used, and that peat and its by-products possess properties of value. But in the last analysis men engage in industry for profit. Therefore, in the establishment and development of any industry certain things of a commercial nature must be carefully considered if success is to be attained. It is not enough to merely know the properties of peat. Its advantages and disadvantages must be shown. Such subjects as location, transportation facilities, markets, capitalization, labor conditions, the selection of sites for buildings, the laying out and construction of plants, processes of manufacture, amount and character of raw material available, cost of handling, working and marketing, etc, must be carefully and thoroughly studied.

Some of these fundamental economic principles are briefly indicated in the following pages.

Location.—Much attention must be given to the location of the bog upon which peat operations are contemplated. The bogs' location with respect to labor supply, markets, transportation facilities, distance from coal supplies, etc., determines to a very large extent what the cost of manufacture and marketing will be. These factors are inter-related and dependent upon each other.

Transportation Facilities.—Unless a peat deposit is located on or near a transportation line, either rail or water, or unless such facilities can be obtained without great expense, its commercial value cannot be considered large. Carting and teaming of peat fuel to centers of consumption is a costly process, owing to the bulkiness of the fuel, therefore, direct rail or water connections with markets is almost a necessary requirement.

If, however, it is intended to gasify the peat directly at the bog and convert the energy into electricity, the transmission lines take the place of transportation routes and this factor is less important. Also, if the intention is to utilize the peat by conversion into gas to be transported in pipe lines, the cost of these rather than rail or water facilities governs. A number of peat fuel plants have failed on account of the lack of proper transportation facilities for getting the finished product to market.

Market.—The market for peat is a factor of great importance in the consideration of the development of a peat deposit. There must be a sale for the finished peat, and at a profit, otherwise there

is no reason or incentive to develop the deposit. As a general rule, at the present time there is no market for peat, since people are not familiar with it. Hence, in the United States, a market must first be created. Many business men and economists maintain that the supply of fuels like wood, coal, oil and gas is still so abundant, and that these, as well as other raw materials of production, are so much better and cheaper than peat, that there will be no market for peat products, at least not for a great many years to come—not until the other materials become rare and costly. The development of any peat project, therefore, depends primarily upon the finding or creating of a market. Without a good market, and a ready sale at a price to yield a profit over and above all costs, including maintenance, interest, depreciation, etc., the industry cannot be developed nor can it exist.

The possible markets and costs of selling must be investigated with considerable thoroughness.

Prospecting and Testing the Deposit.—Preliminary testing and prospecting of a peat deposit will often determine at once whether or not it has any value. But when commercial development is contemplated much more extensive and careful testing is necessary. The different parts of a deposit are often so variable that the material can be worked up with difficulty. Some parts of a deposit may be of extremely good quality, others worthless. Very large bogs of great depth need little careful prospecting because the quantity of material they contain is considerable. But small bogs need much more extensive prospecting in order that the chance of error in estimating may be reduced to a minimum. Physical and chemical tests must be made to determine to what uses the material may be put.

Prospecting is sometimes extremely deceptive and should be done with great care or by men familiar with the work. For further information on prospecting see p. 68.

Quantity of Peat Available.—An estimate of the quantity of peat available in the deposit is of great importance and is essential before other plans are made. The size of the plant, the amount of the investment in plant and equipment, the life of the plant, are directly dependent upon the quantity of material available. A sufficient quantity to warrant the investment must be shown to exist.

Fuel Value of the Peat.—The quality of the finished product for heating purposes depends of course, upon the fuel value of the peat in the deposit. The reputation of the plant and its good will grow out of a high quality of product with respect to fuel value, ash content, cleanliness and the manner in which it burns.

Ash Content.—High ash content is detrimental to the fuel value of peat. Because of their location certain bogs are likely to have a high ash content as a result of soil, sand, silt, etc., being washed in by rains, streams, etc.

Sources of Contamination.—The ashes of peat come from mineral matters accumulated by the peat forming plants during their growth. Mineral matters may also get into the peat deposit by being carried in by water of rivers, lakes, streams, or springs. Heavy rains often wash much soil into peat bogs, especially in sections where timber has been stripped from the land. Fine mineral matter in the form of dust and sand is often blown upon peat deposits by the action of the wind. Certain aquatic plants by their cell actions separate calcium, magnesium, silicon, iron and other metallic salts from the water in which they grow. Often great quantities of the remains of crustacea or shell animals are found in deposits. Marl often is an ash forming material in peat beds.

Drainage.—Possibilities for the drainage of the deposit should be carefully studied as it is almost necessary that peat deposits be drained before they can be profitably used. Drainage frees the peat of a large part of the 80 to 90% of water which it contains in its natural state. A comprehensive drainage scheme must be worked out and the cost of ditching and draining carefully considered. Surveys of the land showing levels and the fall of the land to the nearest drainage basin must be made.

Sometimes, however, draining may not be feasable or necessary. In this case dredging and digging methods are necessary.

If the deposit is to be used for cranberry culture, a system of dams and ditches must be designed.

Character of Surface Covering.—The surface covering of a peat deposit must be carefully studied. Often dense growths of vegetation, trees, shrubs, roots, stumps and buried logs are found upon deposits and these must be removed at considerable expense before the deposit can be worked. Sometimes, however, the wood may be sold and the work of clearing partly paid for in that way.

Preliminary Testing of Machinery.—Mechanical tests of both the peat and the machinery with which it is to be worked should not be omitted, for they are often more valuable than either physical or chemical tests. If possible, a large quantity of the peat from the deposit proposed to be worked should be tested out in plants already established or at the factory of the makers of peat machinery rather than in temporary machinery at the bog. Samples chosen for such

testing should be fair average samples from all parts and depths of the bog, the truth concerning its properties being the only thing sought. Such testing with peat machinery will show whether or not the peat and the machine are adapted to each other. Often they are not and the machinery must be modified. But the invention and development of new machinery is a costly undertaking.

*Character of the Plant.**—"The character of the plant will in large measure be determined by the size of the projected operations, by the process of preparation adopted, and by the available capital.

If machine peat is to be produced, the permanent buildings need not be more extensive than those of a sawmill, and may consist of a shed for protecting the boiler, engine and grinding machinery and the storage bins. The type of construction should be the cheapest and simplest consistent with durability for the expected life of the plant, and as this material will usually be produced only during the summer, no provision against cold weather will be necessary. Many European plants for making peat fuel of this class are without permanent buildings of any kind, the machinery being all movable and housed temporarily at points on the surface of the bog as near as possible to the openings where excavating is being done, and the number of such units being increased as the necessity for them grows.

If briquetted peat is to be produced, the buildings will have to be somewhat more durable and extensive, but need not be of expensive construction. The buildings for a coking plant would require still more outlay for housing the greatly increased bulk of apparatus, especially if the by-products are to be utilized, and the same may be said of the buildings required for a plant utilizing the peat for gas. Even here, however, the expense of the construction can be reduced by exercising care to develop the simplest buildings which can be used for the purpose intended."

Location and Plan of the Plant.—"The main structures of the plant should be so located with reference to the workable part of the deposit that the raw, wet peat, as it comes from the bog, will have to be transported the shortest possible average distance to the grinding and the drying sheds. For this reason the center of the bog would be the ideal site for the factory, if it were to be permanently located; or a movable plant in the vicinity of the main openings would be still better. Practically, in most cases, it will not be possible to place the machinery on the bog, and the next best site will be on its margin, as close by as firm ground can be found to

*Bastin, E. S., and Davis, C. A., "Peat Deposits of Maine." Bull. 376, U. S. Geol. Survey, p. 30.

give the buildings and machinery a secure foundation, and at such a point that the hauls necessary to get the freshly dug peat to the buildings will average as short as possible during the whole life of the plant—that is, somewhere near midway of the margin on one of the long sides of the deposit, although the selection of the site may be affected by some other consideration, such as proximity to railroads or other transportation lines, or to a town, or to favorable drying grounds.

"The laying out of the plant, the location of machinery in the buildings, and the placing of the drying grounds in relation to the buildings must all be carefully considered, to reduce the processes so far as possible to an automatic arrangement requiring the least possible amount of attention and labor. Every point where machines can replace human labor should be considered and, if possible, the machinery installed.

"It must be remembered constantly that in peat-fuel production the problem is how to get from a ton of wet peat, as it comes from the bog, the approximately 225 pounds of salable material which it contains so cheaply that the cost of digging, transporting, preparing it for sale, and selling it will not exceed the price that can be obtained for the prepared material in open market. It is evident that the omission of any expenditures which can be avoided in the course of proper preparation will aid, by so much, the solution of this problem. It seems to follow also that the simpler and fewer the processes of preparation by which salable material can be put on the market the more likely the manufacture is to prove profitable."

Working Capital and Capitalization.—"It is probable that no factor has been more fatal to successful development of peat industries in this country than failure to provide working capital. Apparently investors have been so sanguine of success that they have thought it necessary only to plan to make peat fuel and assemble a portion of the plant, after which the industry would establish itself and immediately give sufficiently large profits to pay dividends and go on with the manufacture indefinitely. These anticipations not having been realized, the investors have refused to advance further funds, long before the plant has passed through its experimental stage and reached that of commercial production. If, however, a sufficiently large part of the funds available at the outset had been reserved to develop the business, as is generally done in other industries, the amounts necessary to extend the plant, after its success was demonstrated, would have been available.

"The amount of capital required will vary according to the process of manufacture adopted, the quantity of product to be manufactured, and other factors not requiring discussion here. In general, it may be said that large capitalization is not required nor desirable in peat enterprises, but that the more simple methods of manufacture can be established at small outlay as compared with those requiring heavier machinery, more handling, and stronger construction of buildings. Attention should also be called to the much larger paid-in capital required to develop a plant to the self-supporting stage with machinery specially designed for some new process of treating peat, than would be needed to do the same work with machinery that has been already thoroughly tested in actual manufacture of the product it is expected to make."

Costs of Working, Manufacture, Marketing, Sale, etc.—A careful study should be made of European methods of working peat and its preparation for market. The costs of working, manufacturing, marketing, etc., are very important and determine the success of the enterprise. The applicability of European methods to American conditions must be carefully studied.

The Labor Question.—In Europe the labor used in the manufacture of peat fuel comes almost entirely from farm hands during slack periods. This condition is, no doubt, responsible for the low cost of production in peat processes. Such a labor situation would probably not prevail in the United States where labor costs are considerably higher and where large scale production, specializing of operations, and division of labor are the rule.

Length of Operating Season.—Climatic conditions determine the length of the operating season. In certain parts of the United States it will not be possible to work peat deposits except for six months during spring and summer. In other parts of the country the season may continue longer. The bearing of length of season should be thoroughly analyzed.

The Essentials of a Successful Enterprise.

Mr. H. F. J. Porter, M. E., in a lecture before the Alexander Hamilton Institute, mentions the following essentials which every enterprise must possess in order that it shall be financially successful.

1. A useful article to manufacture for sale.
2. A properly organized company.
3. Sufficient capital to exploit and carry out the project.
4. A well-defined business policy.

5. An honest, tactful, and capable business manager.
6. A suitable location for the factory.
7. A well-designed plant.
8. A loyal and skilled organization.
9. Perfection in design of the product.
10. Perfection in manufacture, both in material and workmanship.
11. An efficient selling force.
12. A comprehensive system of accounting.

PART II.

THE PEAT DEPOSITS OF WISCONSIN

RELIEF MAP OF WISCONSIN
Photographed from Relief Model of the State
Made by Geological and Natural History Survey.

CHAPTER III

THE FACTORS INFLUENCING THE FORMATION OF PEAT

PHYSICAL GEOGRAPHY OF WISCONSIN

Topography

An essential factor in the formation of peat is a land surface of such a nature that water does not find ready means of escape into drainage channels. The topography of Wisconsin presents an abundance of areas of this sort. From the point of view of its influence on the formation of peat the topography of this state falls into two main types—the Drift Area, which includes over three-quarters of the state—and the Driftless Area, which includes most of the southwest quarter. The characteristic differences in the two general types of topography are appreciated at once on inspection of the relief map, Plate IV.

In the Driftless Area the streams have been at work without interruption for long geologic ages. They have cut their valleys deeply into the surface so that lakes and swamps are almost entirely lacking. The drainage has developed a fairly regular tree-like pattern with the main streams compared to the trunk of the tree and the tributaries of various sizes compared to the branches and twigs.

The whole state once had a surface characterized by the same general type of topography, with streams well developed, draining the land as completely as the driftless area is drained at present. A change of climate and other physical conditions caused great continental glaciers to advance over the state. These glaciers carried great quantities of drift, bowlders, sand, gravel, and clay; and when they melted away this drift was left as an irregular covering over the northern and eastern parts of the state. This drift cover varies in thickness from a thin veneer to 500 feet or more and has completely altered the character of the topography. The great glaciers reduced the hills to some extent and filled the old valleys in irregular fashion, so that now the Drift Area is characterized by numerous undrained depressions, many of which contain swamps or lakes. The moist

climate succeeding the glacial period favored the rapid growth of water plants in these undrained areas and the decay of this vegetation gave rise to numerous large deposits of peat.

The general elevation of the state is also a topographic feature having great influence upon the long duration of these undrained areas. The difference in elevation between the lowest and highest known points is 1359 feet but the general elevation varies only from 600 to 1500 feet above sea level—a difference of only 900 feet in a distance varying from 100 to 250 miles, so the eroding action of the streams in cutting their channels deep enough to drain the depressions left by the glaciers has not been rapid. As a consequence, the growth of the vegetation which produced the peat bogs has not been materially interfered with by lowering the water level and draining the marshes.

Climate and Weather Conditions

The climate and weather conditions of Wisconsin are not unlike those of similarly located areas; that is, they are typical of land areas lying near the center of the continent and removed from the influence of the oceans. However, Lakes Superior and Michigan, lying north and east of Wisconsin, with their combined water area of 54,000 square miles exert a marked influence upon the weather conditions. On account of being thus situated, Wisconsin has a temperate climate. The summers are warm, with short rains, clear skies, large amounts of sunshine and frequent thunderstorms. In the winters extreme and long continued cold weather prevails, the skies are clear, the air is dry, healthful and less chilly than in more humid atmospheres. Snow storms are common in winter but the snowfall is usually light. The prevailing winds are from the west. Frosts occur in the spring and fall but their severity is lessened by the Great Lakes and, consequently, vegetation is affected correspondingly.

The two great lakes have a surface temperature which approximates a maximum of 46° F. and a short distance below the surface the temperature is practically constant at about 39° F. throughout the year. This large volume of water, acting as a reservoir of heat, raises the temperature in the winter and lowers it in the summer and, therefore, the climate of Wisconsin is more temperate than that of the more western interior states which are removed from the influence of the Great Lakes.

Temperature

Wisconsin's summer temperatures average about 60° in the north and about 70° in the south, while the winter temperatures range between the averages of 15° in the north and 25° in the south. The average maximum temperature is generally between 90° and 95°, and seldom exceeds 100° F.; the average minimum is between 10° and 25° below zero.

A table giving the highest and lowest temperatures for each month of the year covering a period of twelve years shows January to be the coldest and July the hottest months in the year. This table gives the maximum temperature observed for January during that period as 59° and the minimum as 43° below zero, a range of 102°. During July the maximum was 101° and the minimum 40°, a range of 61°. The range in temperature during the winter is greater than in summer.

The temperature throughout the state is very even and uniform, there being a difference of less than 10° between the extreme north and south.

As already mentioned, the Great Lakes affect the temperature of the state in such a way as to elevate it in the winter and lower it in the summer. Hence, the temperature near the lake shore is more even than elsewhere in the state. In the summer, lines showing points of equal temperature, or isotherms, cross the state from northwest to southeast, bending southward in the eastern part of the state, thus showing the effect of the lake in cooling this lake shore region. In the winter these isotherms run in an opposite direction, from southwest to northeast, and are forced north by the warming influence of the lakes. These lines take a perceptible northward bend near the lake shore.

Rainfall

The average rainfall is between 32 and 33 inches for the state and it is evenly distributed, being slightly greater in the east than in the west. Throughout the year, however, the precipitation is not uniformly distributed; the greatest amount falls between June and October, while the least falls between November and February. Over 60% of the rainfall occurs in the summer and autumn.

By seasons, the mean rainfall is 7.6 inches in spring, 11.7 in summer, 8.3 inches in autumn and 4.7 inches in winter, or a total of 32.3 inches.

The annual precipitation in Wisconsin is subject to material changes from time to time, there being a recurrence of wet and dry seasons that is quite appreciable. For a period of years the annual rainfall is greater than the average and this period is in turn followed by a series of dry years during which the rainfall is below normal. The time required to pass through a cycle of this kind is not well defined but Kirchoffer* states that exceptionally dry periods occur about once in fifty years, dry periods, once in twenty five years and moderately dry periods, once in ten years.

Water Supply

Wisconsin has water supplies in great plenty in its many streams, lakes, springs and in its ground water. There are 1590 square miles of water in Wisconsin, which represents nearly 3% of the total area of the state. Streams occur in large numbers and are fairly uniformly distributed, being more abundant in the northern part of the state. Here there are few townships which do not have one or more streams. Lakes are also very plentiful. There are over 1400 lakes in the state, of which 1200 are located north of Grand Rapids. In many districts large bodies of ground water lie just below the surface as in Adams, Juneau, and parts of Monroe, Wood and Portage Counties. Plenty of good water is found at medium depths in most places, wells ranging from 15 to 30 feet deep being common. Springs occur in large numbers, many of the lakes being fed in this manner.

General Vegetation and Forest Conditions

Originally Wisconsin was almost entirely covered by forests. The northern and eastern parts of the state were thickly wooded but prairies were found in the southern and western parts. Oaks, poplars, hickories, and trees usually associated with them, predominate in the south and west. The eastern section of the state has great tracts of such trees as maple, elm, ash, etc. The great lumber region of Wisconsin lies in the northern part of the state

*Kirchoffer, W. G., "The Sources of Water Supply in Wisconsin." Bull. University of Wisconsin, Engineering Series No. 106.

which was originally covered by an extensive forest of pine, hardwood and a mixture of conifers and deciduous trees. This region contained great groves of pines, hemlocks, and spruces, and, on account of the quantity and quality of its timber, Wisconsin has long been prominent in the production of lumber and lumber products. Much of the original timber has been cut and fires have consumed and destroyed vast tracts of forest. Consequently, great areas of waste land have resulted. But many of these have since developed a second growth of dense thickets of both hard and soft timber and brush.

Vegetation Concerned in Peat Formation

The peat of Wisconsin may be considered to have been formed by two principal classes of plants which may be broadly classified into; I, The Mosses, and II, The Grasses. These groups may again be subdivided and we have the following classification.

I. Moss Peat.
- (*a*) Sphagnum Peat.
- (b) Hypnum Peat.
- (*c*) Forest Moss Peat.

II. Grass Peat.
- (*d*) Sea Peat.
- (*e*) Carex Peat.
- (*f*) Eriophorum Peat

(*a*) *Sphagnum Moss.*—This is made up of the remains of sphagnum, a form of moss having white leaves slightly tinged with red or green, which grows in marshy places It is sometimes called bog moss or peat moss. These plants are widely scattered over the temperate parts of the earth, there being about 25 North American species. From the soft, limber character of sphagnum it resembles large sponges. It grows in large compact tufts or patches on the surface of bogs or floats in stagnant water.

(*b*) *Hypnum Moss.*—This is the largest genus of true moss and is often called feather moss. It embraces a great variety of mosses, there being about 200 North American species. It is widely distributed in all parts of the world. Unlike sphagnum the hypnum does not absorb moisture readily.

(*c*) *Forest Moss.*—Various mosses, heath plants and the residue of forests go to make up peat of this class. Of the mosses there are always small amounts of sphagnum and hypnum found with

tree moss, broom moss, and several other varieties. Mosses belonging to the variety Lycopodium, or fir-moss, and other moss-like low plants with evergreen leaves, like ground-pine and club moss, help to produce peat. Then, under this heading are included the Polytrichum mosses such as hair cap moss and bear moss. The lichens, fungi, ferns and other cryptogamic plants, together with their spores, and certain forms of algae, also assist in peat formation. Cassandra, andromeda and various other heath plants occur in abundance on peat bogs. In addition, peat deposits are found to contain leaves, trunks and roots of trees together with other kinds of forest residue.

(*d*) *Sea Plants.*—Under this heading are included plants which live in lakes, streams, etc., or at the borders of such situations, and which require much water for their support. The sea plants may be subdivided thus:—

Phragmites.—Marsh reed and reed-grass.

Scirpus.—These embrace water plants known as bulrushes, or club-rushes. The plants have a tall, smooth, round stem and they are found projecting from shallow lakes and rivers.

Equisetums.—Herbs having hairy, hollow jointed stems and no true leaves. They include the horsetails or swamp horsetails.

Menyanthes.—These are herbaceous water plants, with creeping root stock, and bear white or bluish flowers. Marsh trifoil, bog bean or buckbean belong to this class.

Nymphaea.—Aquatic plants having white, blue, pink or yellow flowers. Their common names are waterlilies and pond lilies.

In addition, there are other forms of water plants entering into the formation of peat. Among these may be mentioned calamus, sweet flag, white flag, cat tails, pondweeds and other aquatic plants.

(*e*) *Carex.*—Carex plants are a numerous and widely distributed class of grass-like herbs of the order Cyperaceae. These constitute the sedges, of which there are about 700 species known. The sedges are innutritious and differ from the grasses in this respect. Growing in dense tufts in marshy places, they have triangular, jointless stems, clustered flowers, and long grasslike leaves which are usually sharp and rough on the margins and mid rib.

TYPICAL VEGETATION BORDERING UNIVERSITY BAY MARSH, MADISON, DANE COUNTY

Here several varieties of aquatic plants may be observed. Among these are arrow-leaf, sedges, grasses, rushes, reeds, and wild rice. The open water is entirely covered with a small, green, floating pond weed.

SHOWING ARRANGEMENT OF VEGETATION BORDERING UNIVERSITY BAY MARSH, MADISON, DANE COUNTY

1. In the foreground are pond lilies; the water here is clear
2. Next come the cat-tails.
3. Farther back are cat-tails and wild rice.
4. In the background are willows, maples, etc.
5. In the water area in the background is shown a variety of floating water plant which covers the water completely. Out in the water, and not showing in the picture, are bulrushes, wild celery, reeds, and other water plants.

This zonal arrangement is typical at the edge of marshes bordering on water.

(*f*) *Eriophorum*.—Peat-forming grasses are found in great abundance. There are many varieties of grasses growing upon marshes and which are cut in dry seasons to furnish marsh hay or meadow hay. The grasses differ from the sedges in that they are nutritious, have soft stalks or stems and long, narrow blades, the jointed and tubular stems bearing fruit in the form of clusters of mealy or flowering seeds. Cotton grass (Eriophorum virginicum) and wool grass (Eriophorum cyperinum) are common varieties found upon peat deposits.

Plants Commonly Observed on Wisconsin Peat Deposits

Among the many kinds of plants found upon the peat deposits of Wisconsin the following are easily recognized and occur in abundance. Their common names are given.

Andromeda, Arbor Vitae or White Cedar, Trailing Arbutus, Broad Leaved Arrow-Head, Ash, Balsam or Fir Balsam, Marsh Blue-flower, Birch, Blueberry, Blue Flag, Buckbean, Bulrushes, Bur-Marigold, Cassandra, Cat tail, Cedar or White Cedar, Bog Club-Moss, Water Club-Rush, Cotton-Grass, Cranberry, Water Dock, Ferns, Golden Rod, Many varieties of Grasses, Hemlock, Horsetail, Hypnum Moss, Labrador Tea, Larch or Tamarack, Sheep Laurel, Lichens, Wild Mint, Hair-cap Moss, Various other Mosses, Pickerel Weed, Jack Pine, Norway Pine, White Pine, Indian Pipe, Pitcher Plant, White and Yellow Pond Lilies, Pond Weeds, Rushes, Reeds, Various Sedges, Smartweed, Sheep Sorrel, Sphagnum, Spruce, Sweet Flag, Tamarack, Water Lily, Willows, Wintergreen, Wool Grass.

Relations Between Physical Geography and Peat Formation

It is evident, from the foregoing brief consideration of Wisconsin's topography, climate and vegetation, that this state possesses, to a very marked degree, the conditions favorable and essential to the formation of peat. It is also evident that the relations existing between the various factors and peat formation are quite complex. The following discussion of Wisconsin peat by Chamberlin shows some of the inter-relations of some of these factors.*

"When the glacier retired from our state, it left its debris in the form of drift heaped up in an irregular way over the surface, giving rise to numerous depressions which soon filled with water, resulting

*Chamberlin, T. C., "Geology of Wisconsin," 1873-1879. Vol. 2, p. 240.

in lakes of various forms and sizes. It is perhaps not too much to say that within our district, these numbered thousands. In most cases they soon filled to the brim and then began to overflow their margin at some point, thus forming a channel, which was rapidly cut deeper and deeper, at the same time draining the lake. As the water became shallower, vegetation sprang up in the form of reeds, flags, rushes and the so-called water mosses, which, on dying, fell to the bottom of the lake, and being prevented by the water from complete decomposition, accumulated as a peat deposit. As the draining continued, these lakes became marshes, and a new class of vegetation sprang up, varying according to the character of the marsh formed.

"In the region now occupied by prairies and by oak openings, the marshes were occupied generally by members of the grass or sedge group, accompanied with those mosses that are usually found associated in this group. As the vegetation thus produced died with the succession of seasons, it was added to the accumulating peat deposit. In the more heavily timbered regions of the state, the marshes usually came to be occupied by the swamp-frequenting conifers, the most abundant of which is the tamarac. In association with these there is everywhere to be observed a luxuriant growth of minor vegetation, among which Sphagnum mosses are most efficient in peat production. These have the property of dying below while growing densely above, and thus they contribute to the rapid accumulation of vegetable debris, and for this reason they take foremost rank as agents of peat formation. They are not confined in their association to the arboreus vegetation named, but in the region under description are most abundant in that connection.

"In regard to the amount of peat formed in these several ways, the order will be the reverse of that in which they are named. The accumulation appears to have been much more rapid in the tamarac and similar swamps, than in the open marshes, and as a result the deposits of these marshes are almost universally found to be deeper than those of the other class. The amount of accumulation that took place in the open marshes, after they became such, was undoubtedly much greater than the accumulation during the period that they existed as lakes.

"Aside from the accumulation of peat in these extinct lakes, deposits arising in similiar ways took place in wet localities in connection with running streams, or in wet valleys, that bear no evidence of having once been lakes.

"Bearing in mind the method of formation, it will readily be anticipated that great variety in the character of the peat will be the result. Its degree of decomposition ranges from merely dead vegetation to that which has become thoroughly disintegrated, and the value of any given deposit will depend in part upon its character in this respect, since the fibrous condition of peat is one of the serious obstacles to its profitable utilization. It will also be readily understood from its mode of origin, how impurities may become incorporated with it. On the margin of the marsh, the wash from the adjacent uplands will naturally introduce more or less of earth or sand. Near the bottom of the bog, earth will naturally become incorporated with the peat, and in those cases where the surrounding regions have in recent times been cultivated, the unusual amount of earth carried down by the waters will render the entire surface of the peat more or less impure. That portion of the peat which accumulated while the lake was gradually becoming drained to a marsh is more or less filled with the shells of snails, and the remains of other animals that inhabited the lake. In many cases the amount of accumulation of this kind is very considerable, sometimes equaling and occasionally surpassing the accumulation of the peat itself, forming a mixture of marl and peat that will prove very serviceable as a fertilizer. Where the peat accumulated in the vicinity of running streams, their periodical overflow has contaminated the deposit in a greater or less degree. A fourth source of impurity arises from travertine, or calcerous tufa, deposited from springs. This, while it is detrimental to peat as fuel, enhances its value as a fertilizer. Hence, in the selection of peat marshes, those which have been, from their situation and nature, sheltered from these sources of impurity, will, to that extent, be favorable to a pure deposit. The situation and the nature of the marsh will also furnish some indication as to the abundant presence or comparative absence of the acids which interfere with the direct use of peat as a fertilizer. The character of the vegetation growing upon the bog will, however, be a more reliable indication of this. The presence of shells or marl may be taken as satisfactory evidence of the absence of any harmful quantity of these acids. The number of deposits of peat within this portion of the state is very great, and their purity ranges through all degrees, from a very slight impurity, to that which is more properly called muck. The depth of these deposits is also exceedingly varying. In the investigations of the survey, an auger capable of penetrating 12½ feet was used.

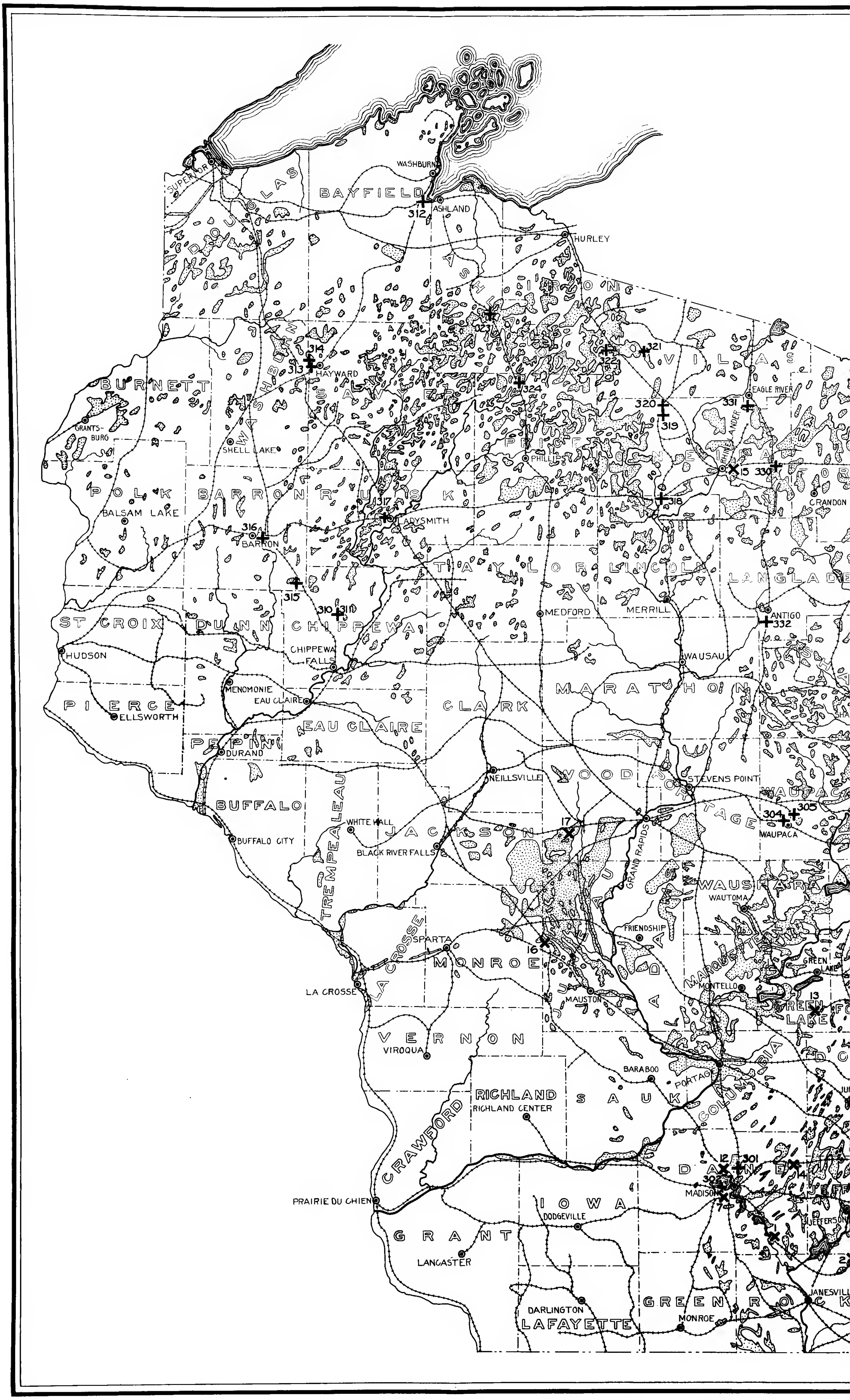
In most of the peat deposits occupying open marshes, this was found sufficient to penetrate to the bottom. In most of those arising from the sphagnum mosses in the forest region, the depth was found to exceed that amount. In some cases marshes were said to have a depth two or even three times that amount. The quantity of peat in eastern Wisconsin is to be reckoned by millions of tons."

Geographical Distribution of Peat in Wisconsin

Peat is found in many parts of Wisconsin. It occurs in beds varying from 1 or 2 to over 20 feet in depth and from 10 to 30,000 or more acres in area. That near the surface is in an imperfect state of decomposition and is light, spongy, fibrous and of yellow or light reddish brown color. Lower down the peat is more compact and darker colored. The lowest layers are almost black in color, pitchy and slippery and almost fibreless in structure.

The accompanying map shows the location of the peat deposits which have been prospected and which are described in this bulletin. These deposits are but a small portion of those existing in the state and are to be considered as showing representative examples rather than the total number of deposits. Other deposits, perhaps equal in area and importance, exist, but it would have been impractical to have more thoroughly investigated all of them with the time and funds available. As will be seen from the map, the deposits examined are fairly well distributed and are not confined to any particular districts or sections. (See Plate VI).

Some idea of the location and distribution of Wisconsin's marsh and peat soils can be obtained from this map which has been prepared from the most accurate data available. Topographic maps made by the U. S. Geological Survey were used for the southeastern part of the state. Soil maps made by the Wisconsin Geological and Natural History Survey were used for the following areas: North central Wisconsin, north part of northwestern Wisconsin, south part of northwestern Wisconsin, Bayfield area, Superior area, Viroqua area, Vilas and portions of adjoining counties, and also for Fond du Lac, La Crosse, Kewaunee, Juneau, Waushara, Waukesha, Iowa, Columbia and Marinette counties. The remainder of the information was taken from the soil map of the state in the atlas of the former state geological survey (1873-79).



SUPERIOR
DOUGLAS
BAYFIELD
WASHBURN
ASHLAND
312
HURLEY
IRON
ASHLAND
VILAS
321
322
323
324
314
313
HAYWARD
SAWYER
WASHBURN
BURNETT
GRANTS-BURG
SHELL LAKE
PRICE
PHILLIPS
320
319
EAGLE RIVER
331
RHINELANDER
15
330
ONEIDA
CRANDON
POLK
BARRON
RUSK
BALSAM LAKE
317
LADYSMITH
316
BARRON
318
TAYLOR
LINCOLN
LANGLADE
315
310
311
MEDFORD
MERRILL
ANTIGO
332
ST CROIX
DUNN
CHIPPEWA
HUDSON
CHIPPEWA FALLS
WAUSAU
MENOMONIE
EAU CLAIRE
PIERCE
ELLSWORTH
CLARK
MARATHON
EAU CLAIRE
PEPIN
DURAND
NEILLSVILLE
WOOD
PORTAGE
STEVENS POINT
BUFFALO
WHITE HALL
JACKSON
17
304
305
WAUPACA
BUFFALO CITY
BLACK RIVER FALLS
GRAND RAPIDS
TREMPEALEAU
JUNEAU
WAUSHARA
WAUTOMA
FRIENDSHIP
ADAMS
SPARTA
MONROE
16
LA CROSSE
LA CROSSE
MONTELLO
MARQUETTE
GREEN LAKE
13
MAUSTON
VERNON
VIROQUA
BARABOO
PORTAGE
COLUMBIA
RICHLAND
RICHLAND CENTER
SAUK
CRAWFORD
12
301
DANE
14
302
MADISON
7
PRAIRIE DU CHIEN
IOWA
DODGEVILLE
GRANT
LANCASTER
DARLINGTON
LAFAYETTE
GREEN
MONROE
ROCK
JANESVILLE

Missing Page

The information from this old map is the least accurate and there are doubtless many peat tracts that the map does not show at all. Nevertheless, the map serves a useful purpose in indicating districts where peat is likely to exist.

Destruction of Peat by Fires

During recent years there have occurred a number of unusually dry periods and, as a result, the swamps and marshes of the state are much drier than formerly. This condition has caused extensive and repeated marsh fires, as well as forest fires, which have consumed large amounts of moss and peat. Burning peat marshes often may be seen in the late summer or fall. The fires continue for weeks, large quantities of peat are consumed and the consumption of fuel often continues until considerable depths have been reached.

Hence, a destruction of peat resources takes place which is extremely rapid and all out of proportion to the length of time required for the peat to form. In many cases there is only a small amount of peat left in some of the swamps and marshes.

CHAPTER IV

PROSPECTING AND TESTING PEAT DEPOSITS

Prospecting Methods

Certain schemes are usually followed in estimating the character and extent of peat deposits. These schemes are all more or less similar but vary as circumstances may require. Generally there are two examinations of the deposit—the preliminary and the final.

In the preliminary examination certain general and approximate observations are made which allude to such features as topography, location, transportation facilities, possible markets, type of deposit, vegetation, area and depth of peat, quantity available and, in addition, a few average samples are collected and analysed. Such a preliminary examination will usually show whether or not the bog is suitable for development and, if not, further prospecting is not worth while. If, however, the preliminary reconnoisance indicates that the deposit is probably suitable for development, a more careful, complete, detailed investigation is made.

During the final inquiry the marsh is surveyed, its outlines and levels determined, and detailed maps showing elevations, boundaries, contours, distances, principal topographical features, etc., are prepared. The possibilities of drainage are considered. Final estimates of area, depth of deposit and amount of peat available are collected. Samples of peat are taken with sounders or sampling tools and analysed or tested in some satisfactory manner. Thus, the uniformity and composition of the peat in different sections of the deposit are thoroughly investigated. To aid in this, the marsh is often divided into squares with sides ranging from 100 to 300 feet in length and samples are collected at each corner from different depths. These data also assist in drawing profiles and sections of the arrangement and slope of the various layers of the bog.

In prospecting the peat deposits of Wisconsin, the methods now to be outlined were used and adhered to as far as possible for each deposit studied.

General Observations

With the aid of a general map of soils a particular section of country in which peat was likely to be found, was determined upon for exploration. A visit was then made to the deposit and here ob-

servations concerning the principal features of the marsh were recorded. These data were more or less general, the mapping of deposits and other detailed studies having been thought inadvisable. Observations were made covering the following points:

1. Location of deposit.
2. Distance from transportation lines and names of same.
3. Distance from and names of nearest centers of population.
4. Approximate area of deposit.
5. (a) Type of deposit; whether marsh, bog or swamp.
   (b) Type of basin; whether shallow or deep.
   (c) Probable method of formation of peat.
6. Character and topography of surrounding land.
7. Nature and kind of vegetation on marsh and surroundings; whether grasses, sedges, shrubs, mosses, trees, etc.
8. Presence of moisture or standing water; whether deposit is drained by stream; presence of near-by lakes; possibilities of drainage or flooding.
9. Miscellaneous or special features. Distances from possible markets. Local industries likely to be able to use peat or products derived from peat. Whether deposit has been or is likely to be injured by forest or marsh fires. Presence of logs, stumps, etc.

Sounding Deposits

After these general features were recorded, the deposits were prospected with special sounders designed for that purpose. For diagrams and descriptions of these see heading "Peat Samplers and Sounders," page 71. Information was thus obtained relating to the following points:

1. Depth and character of surface and lower layers of peat.
2. Depth of whole deposit.
3. Quantity of peat available for fuel.
4. Physical characteristics of the peat such as color; texture; plasticity; amount of moisture; state of decomposition; variation in structure of deposit from top to bottom of marsh; character and arrangement of section of bog; kinds and relative amounts of plant remains, such as seeds, stalks, stems, leaves, etc.; presence of logs, stumps and other coarse material; amount and character of impurities such as gravel, sand, clay, marl; kind of material below peat bed and forming bottom of marsh.

Estimating the Quantity of Peat in a Deposit

An estimate of the quantity of peat available for fuel can be arrived at when the depth and area of the deposit have been determined. Such estimates were made for the Wisconsin deposits and are given in Chapter VII. In reducing the quantity to tons of finished fuel the unit of measurement of 200 tons per acre-foot, adopted by Prof. Chas. A. Davis, Peat Expert, United States Geological Survey, has been used. (An acre-foot is an acre in area and one foot deep). Consequently, if the depth in feet, the area in acres and the constant 200 be multiplied together, the result will represent the number of tons of finished peat fuel available in any particular deposit.

The constant 200 tons per acre foot is arrived at as follows:

One cubic yard of drained and settled bog gives at least about 250 pounds of air-dried peat, containing about 25% moisture*

$$\text{250 pounds per cubic yard} = \frac{250}{27} \text{ pounds per cubic foot.}$$

There are 43,560 sq. ft. in an acre.

$$\text{Hence 1 acre foot will contain } \frac{250 \times 43{,}560}{27} \text{ pounds}$$

or.. 404,000 pounds

and this is.............................. 202 tons.

Therefore, 1 acre-foot contains at least 202 tons of air-dried peat containing 25% water. And since there are 640 acres per square mile, the tons of air-dried peat per square mile foot will be 640 × 202 or 129,000.

Another computation shows about the same thing. Davis and Bastin † estimate that 4 cubic feet of wet peat are required to make 1 cubic foot of air-dried peat. Carter‡ states that air-dried machine peat weighs from 30 to 40 pounds per cubic foot. Then we have the following:

1 cu. ft. wet peat makes $\frac{1}{4}$ cu. ft. air-dried machine peat.

1 cu. ft. air-dried machine peat weighs about 35 pounds (average).

1 acre equals 43,560 square feet.

Then 1 acre-foot contains......43,560 cubic feet wet peat.

And 1 acre-foot will yield .....43,560 × $\frac{1}{4}$ or 10,890 cu. ft. dry peat.

*Nystrom. E., "Peat and Lignite Their Manufacture and Uses in Europe." Bulletin Canada Dept. of Mines. Ottawa, 1908, p. 1.

†Bastin, E. S., and Davis, C. A., "Peat Deposits of Maine." Bull 376, U. S. Geol survey.

‡Carter, W. E. H., 12th Report, Bureau of Mines, Ontario, Canada, p. 199.

Or 1 acre-foot will yield ..... $10,890 \times 35$ or 381,150 pounds dry peat.

Or 1 acre-foot will yield....... $\dfrac{381,150}{2,000}$ or 190 tons dry peat.

Taking these two sets of figures it will be seen that for ordinary prospecting work the following estimates will be near enough.

1 acre-foot will yield 200 tons air-dried machine peat, and 1 square mile will yield 129,000 tons air-dried machine peat for each foot of depth.

Some idea of the great amount of fuel contained in peat bogs can be obtained from the following calculation. If we take, for instance, a bog like that at Fond du Lac, which is a fair sized bog, we find it to have an area of 800 acres and a depth of 7 feet. Hence, the deposit contains 5,600 acre-feet of peat. Since one acre-foot will yield 200 tons machined peat, the bog will produce 1,120,000 tons. For rough calculations it is generally assumed that one ton of coal equals 1.8 tons air-dried peat, as far as fuel value is concerned. This bog then contains the equivalent of 623,000 tons of coal. This represents a considerable money value.

For an estimate of the area, depth and quantity of peat in the deposits prospected during the surveys of 1903 and 1908 see Chapter VII, page 169. Estimates of the total quantity of peat available in the peat deposits of the state are also given in Chapter VII.

Peat Samplers and Sounders

Except in a few cases where briquetted or manufactured peat samples were studied, all of the peat samples described in this bulletin were obtained directly from the deposit by means of one of the sampling tools or sounders now to be described.

The sampler used in the 1903 investigations is shown in Fig. 6. It consists of a twelve-inch piece of two-and-one-half-inch pipe, A, one end of which is toothed, while an iron plug, B, having a one-inch hole, is welded inside the other end. A piece of one-inch pipe, C, nine feet long, is welded into the one-inch hole of the plug, B. A cone-shaped iron plunger, D, having leather packing rings, is slipped inside of the two-and one-half-inch pipe and this plunger is operated by a half-inch rod, E, extending inside of the one-inch pipe.

A sample is obtained as follows:

The cone is pushed down until its apex extends some distance below the end of the two and one-half-inch pipe and so that its mouth

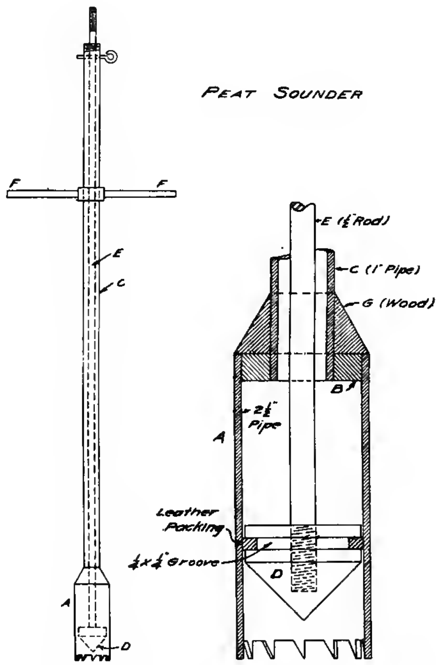


FIG. 6. PEAT SAMPLER USED IN 1903 INVESTIGATIONS

is entirely closed. Then with the aid of the handles, F,F, the sampler is forced down into the deposit to any depth at which it is desired to collect a sample, the pointed cone making this operation comparatively easy. When the desired depth has been reached, the cone is pulled inside as far as possible and the sampler is forced down some distance farther. This operation fills the instrument with peat. Next, the sounder is pulled up, bringing with it a sample of peat. Cone, G, made of wood, diminishes the resistance to pulling considerably. By means of the cone plunger, the peat is forced out of the sounder and placed in a Mason jar.

With the same instrument the depth of the deposit can be determined. To do this, a cap is screwed onto the end of the one-inch pipe and the capped end is forced down into the marsh. A little experience will enable the prospector to judge from the added resistance

when the bottom has been reached and usually he will be able to tell something regarding the nature of the bottom. Thus, it is practically impossible to force the sounder down when sandy or clayey strata are reached. Sand is distinguished by a rasping and scratching feeling and sound. Marl yields easily to the rod. Gravel and logs can be determined after a little experience. After the bottom has been reached, the instrument is pulled up and portions of the bottom will be found adhering to the cap. If the one-half-inch pipe is forced down without a cap some of the material composing the last layer penetrated while the pipe is being pushed downward will be found inside of the end of the pipe.

Additional lengths of piping can be attached and the sounder sent down to greater depths.

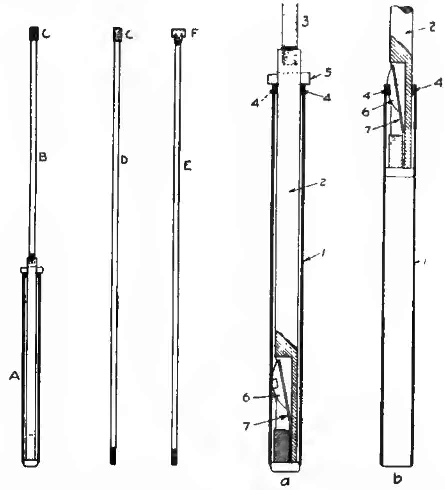


FIG. 7. PEAT SAMPLER USED IN 1908 SURVEY

A lighter and more convenient sounder was used in the prospecting work of 1908. Its construction is shown in Figure 7. A is the sounding knife. The rod, B, made of $\frac{3}{8}$-inch hollow seamless steel tubing, is screwed into the upper end of the sounder. This rod has a coupling, C, at its other end into which may be screwed another section of tubing, D. By coupling several of these sections together, (each section is two feet long), the sounder can be sent to any depth desired. Rod, E, has a short handle, F, at its upper end and is intended to be used as an end rod. Ten of these two-foot rods and the sounder were carried in a canvas case during the 1908 prospecting work and it was therefore possible to make soundings to a depth of 20 feet.

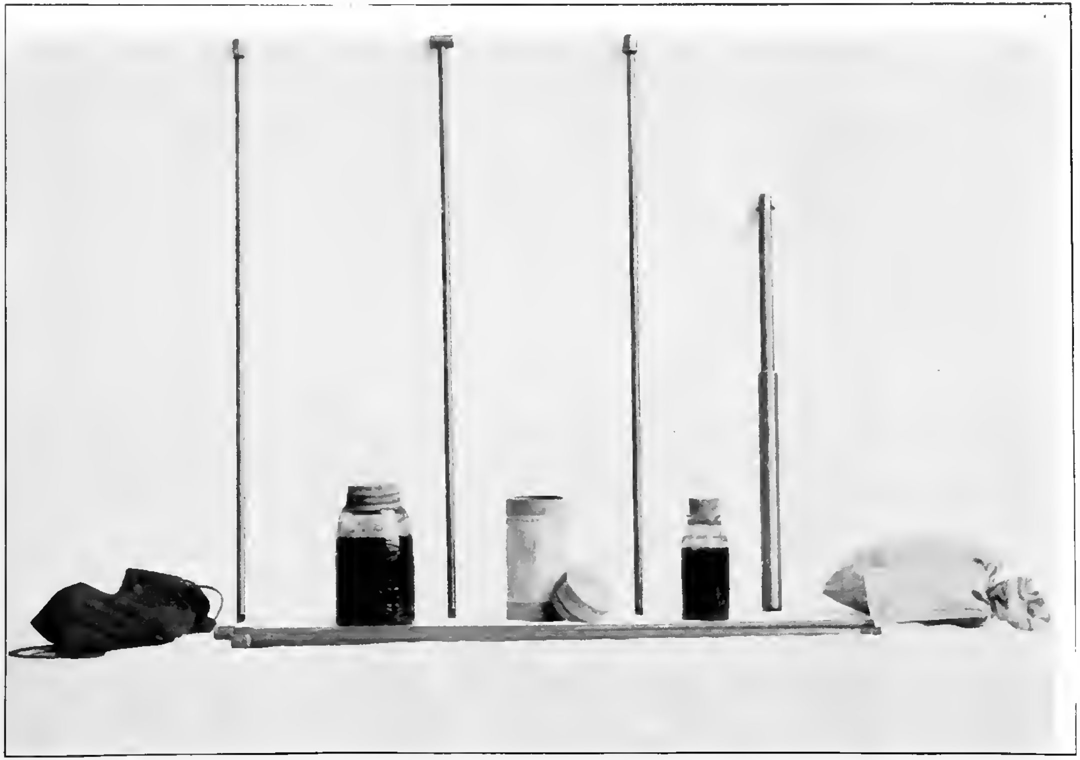
The sounding knife details are as follows:

1. Cylindrical sounding knife, made of brass tubing, diameter $\frac{7}{8}$ inches, length 10 inches, sharpened at lower end, with a brass collar (4) inside of upper end.
2. Brass plunger, diameter $\frac{5}{8}$ inches, length 11 inches. A slot $\frac{3}{16}$ inches wide, $\frac{1}{2}$ inch deep and $2\frac{3}{4}$ inches long is cut in the lower end to provide for catch, (6).
3. $\frac{3}{8}$-inch seamless steel tubing screwed into upper end of plunger, (2).
4. $\frac{1}{4}$-inch x $\frac{1}{8}$-inch brass collar inside of upper end of (1,) to engage with slot in (6).
5. $\frac{3}{8}$-inch x $\frac{7}{8}$-inch tapering iron pin limiting lower position of plunger, (2)
6. Brass catch shaped as shown, $\frac{3}{16}$ inches thick, $\frac{3}{8}$ inches wide, $2\frac{1}{8}$ inches long, fitting into slot in plunger. It has a $\frac{1}{4}$-inch x $\frac{3}{16}$-inch notch to engage with (4).
7. Steel or brass spring tending to force (6) out of slot.

Samples are collected with this instrument in very much the same manner as with the other sounder. Thus, a section of rod is attached to the sounding knife. With the plunger in the position shown at a, the sampler is pushed down into the deposit to the desired depth. It is seen that no material will enter the sampler while the plunger is in this position. When a sample is to be collected, the plunger is pulled up until the catch, (6) engages with collar, (4) as shown at b. The pressure of the peat holds the knife in place while the plunger is being pulled up. Knife and plunger are now locked by catch, (6), in such a way that when the device is pushed down further a sample will be cut out of the deposit. Then the whole instrument is pulled up, the catch released and the sample forced out with the plunger.

If it is desired to merely determine the depth of the deposit, the rod is sent down alone without the sounder.

Some of the disadvantages of this instrument are; samples are small making it necessary to send instrument down several times to collect enough material, catch clogs up with material and fails to work. But these disadvantages are counter-balanced by several advantages, which are; lightness, portability, can be packed into shorter space, easily inserted in marsh, on account of small diameter, can be used at great depth.



PROSPECTING OUTFIT USED IN THE FIELD WORK OF 1908

This picture shows the sounder and extension rods, together with bottles and bags used for collection and shipment of peat samples obtained at the deposit. The sounder and handles were carried in the canvas bag shown at the left of the picture. Samples collected with this tool were preserved in three ways. When the sample was to be preserved in its original condition it was enclosed in either a glass Mason fruit-jar with air-tight screw-cover or in a glass bottle with cork top. In the latter case, the corked bottle, when enclosed in a paraffine-coated, wooden tube with air-tight screw-top cover, was sent directly through the mails. The canvas bag, shown at the extreme right of the picture, was used to ship partially air-dried samples through the mails.

Other Instruments for Obtaining Peat Samples

Sometimes also, peat samples are collected with spades, spade-knives or slaynes, peat augers and post-hole diggers. These tools, however, are likely to collect samples containing a mixture of material from various depths. Hence, for accurate prospecting, it is better to use some form of peat sounder such as those described above, since contamination or mixing of samples cannot take place when such a sounder is used.

Collection and Shipment of Peat Samples

The samples collected with the sounders were preserved, prepared for shipment, numbered and sent to headquarters for examination. In the 1903 survey, the wet material taken from the bog was placed in a one-pint Mason fruit jar having an air-tight cover. Consequently, the original characteristics (particularly the moisture content) were preserved until such time as an analysis could be made. In the 1908 survey this plan was somewhat modified. The wet material taken from the bog was put into a 4-ounce bottle having a cork stopper, and this bottle, in turn, was placed into a standard wooden mailing tube with a screw top cover and a lining of paraffine. In this case the sample retained its original characteristics also. In addition, another sample from the same marsh was collected and the water squeezed out of it as much as possible by hand. This partially dried sample was put into a 6″ x 10″ canvas sack, the top of which was then securely tied. Next, the sack was wrapped in paper and shipped to headquarters for analysis. It is evident that the sack sample was partially dried and therefore did not contain its original moisture content.

The samples collected in the 1903 survey are numbered from 1 to 17, inclusive. Those collected in 1908 bear numbers from 301 to 333, inclusive, the series 300 having been chosen to suit the convenience of the U. S. Geological Survey which used the same samples for some of its work.

Accompanying each sample of the 1903 series was a card bearing its record or history. A sample of this form is shown below. As will be seen, the record was partly filled out in the field and completed at headquarters after tests were made. Each sample of the 1908 series had a record card that was much more complete. Such a blank form is given below also.

RECORD FORM USED IN 1903 SURVEY

UNIVERSITY OF WISCONSIN

DEPARTMENT OF EXPERIMENTAL ENGINEERING

PEAT INVESTIGATION

Made by { .... Date.................................190....

Deposit No.........................

Sample No.........................

Character of Deposit..

Location { State...
County...
Locality...
....
....

Surrounding Topography..

....

Area of Deposit: Acres.............................. Sq. Miles..................................

Depth of Deposit..

Location of Sample in Bed..

Depth of Sample from Surface..

	AS RECEIVED	DRY FUEL	COMBUSTIBLE
Moisture %..............................	....	....	....
Volatile Matter %..............................	....	....	....
Fixed Carbon %..............................	....	....	....
Ash %..............................	....	....	....
British Thermal Units per pound	....	....	....

Remarks..

....

....

....

....

....

Peat Form 1. PEAT SAMPLE (Over)

(A) LABORATORY RECORD NO.________

Designation, ; Tube ; Sack No.

Mailed , 190 ; Received , 190

State, ; County,

Township, ; S., ; T., ; R.,

Town (distance and direction from),

Name of peat bog, ; ft., ; in.,

Owner,

Character of peat,

Analysis desired,

Collector,

Send report to,

PEAT SAMPLE (over)

(B) LABORATORY REPORT

State, ; County,

Township, ; S., ; T., ; R.,

Town (distance and direction from),

Name of peat bog, ; ft., ; in.,

Owner,

Character of peat,

Location of test boring (distance from margin),

Vegetation on bog,

Method of sampling,

, *Collector*.

PEAT SAMPLE (over)

(C) SAMPLE RECEIPT

Designation, ; Lab. No.

Collector, ; Tube ; Sack No.

Mailed , 190 ; Received , 190

Remarks:

SIGNED:

For Chief Chemist.

(D) To MR.

Use one of these forms for each sample.

Do not separate the cards. Fold along dotted lines and mail in envelope addressed to Chief Chemist.

[Front View]

RECORD FORM USED IN 1908 SURVEY

PEAT SAMPLE

(over)

(E) Laboratory Record

Peat wet or dry,

lbs.

Method of sampling,

PEAT SAMPLE

(F) Laboratory Report

Designation, ; Laboratory No.

Air-drying loss, per cent.		Air dried	As received	Dry peat	Peat section	
Proximate.	Moisture,				1	
	Volatile matter,				2	
	Fixed carbon,				3	
	Ash,				4	
Ultimate.	Sulphur,				5	
	Hydrogen,				6	
	Carbon,				7	
	Nitrogen,				8	
	Oxygen,				9	
By calorimeter	Calories,				10	
	B. T. U.,				11	
Calculated from ultimate analysis	Calories,				12	
	B. T. U.,				*Excluded.	

PEAT SAMPLE

(G) TUBE / SACK Tracer

Give copy of inside label and describe any special marks on tube / sack.

(A) To be filled in by collector with exception of "Received."
(B) To be filled in by collector.
(C) To be filled in by chemist.
(D) To be filled in by chemist.
(E) To be filled in by collector.
(F) To be filled in by chemist.
(G) To be filled in by collector.

[Reverse View]

Laboratory Tests of Peat

The samples of the 1903 series were analysed in the Fuel Laboratory of the Experimental Engineering Department of the University of Wisconsin by A. L. Johnson and R. H. Hadfield under the direction of Prof. A. W. Richter. Those of 1908 were analysed under the direction of Dr. F. M. Stanton of the U. S. Fuel Testing Station at Pittsburgh. For all of these samples the principal tests made were (1) proximate analyses for percentages of moisture, volatile matter, fixed carbon, ash and sulphur and (2) determination of heating value in British Thermal Units per pound, with a Mahler's Bomb Calorimeter. In addition, ultimate analyses of a few of the 1908 samples were made in which the percentages of Carbon, Hydrogen, Oxygen, Nitrogen, Sulphur and Ash were determined. The heating value in British Thermal Units was also found with a calorimeter for these latter samples.*

Explanation of Terms

In specifying the quality and characteristics of fuels certain terms are employed which serve as bases of comparison. These are explained below.

Heating Value—The heating value of a fuel is expressed in heat units per unit of weight. Two common heat units are in use—the British Thermal Unit and the French Thermal Unit.

British Thermal Unit—A British Thermal Unit (B. T. U.) is the amount of heat which will raise the temperature of one pound of water through one degree Fahrenheit.

French Thermal Unit—The Calorie is the unit adopted in the metric system and is the amount of heat which will raise the temperature of one kilogram of water through one degree Centigrade.

Relations Between the Two Units—The relations between the two units and the factors entering into them are as follows:

*For standard methods of making tests on fuels consult the following:

Proximate Analysis. R. C. Carpenter, "Experimental Engineering," p. 470. A. H. Gill, "Gas and Fuel Analysis for Engineers," p. 72. "Transactions American Society of Mechanical Engineers," Vol. 21, pp. 63, 65.

Heating Value and Mahler's Calorimeter. R. C. Carpenter, "Experimental Engineering," p. 461. A. H. Gill, "Gas and Fuel Analysis for Engineers," p. 81.

Ultimate Analysis. A. H. Gill, "Gas and Fuel Analysis for Engineers, p. 72. T. B. Stillman, "Engineering Chemistry," p. 23.

1° C.	= 1.8° F.
1° F.	= .556° C.
1 pound	= .4536 kilograms
1 kilogram	= 2.2 pounds
1 B. T. U	= .25 Calories
1 Calorie	= 3.968 B. T. U.
1 B. T. U., per pound	= 1.8 Calories per kilogram
1 Calorie per kilogram	= .556 B. T. U. per pound

To reduce calories per kilogram to B. T. U., per pound, multiply by 1.8

Ultimate Analysis.—All fuels depend for their heating value upon the amount of carbon and hydrogen they contain. Solid fuels contain, in addition to these useful elements, other substances which have no heating value, such as ash, water and oxygen, the latter being combined with the hydrogen and carbon. Small percentages of sulphur and nitrogen are also usually present in fuels but these are of no value. In the ultimate analysis the constituents of the fuel, except the moisture and ash, are determined in terms of the ultimate chemical elements which have just been mentioned.

Proximate Analysis.—An approximate or proximate analysis is usually made which separates the coal into four parts, viz: moisture, volatile matter, fixed carbon and ash.

Moisture, Volatile Matter, Fixed Carbon and Ash.—The moisture in coal usually means the total amount of water present which includes the surface moisture as well as that which is hygroscopic or absorbed by the fuel. Sometimes, however, the two are separately determined. The volatile matter consists principally of the hydrocarbons, or compounds of carbon and hydrogen, which are volatile or easily distilled off. They are driven off and converted into gases by the application of heat. Tar and other smoke producing materials are included. After the moisture and volatile matters have been driven off, there remains a residue containing the fixed carbon and ash. This often forms the solid substance, coke. Fixed carbon, or that which is not volatile, is almost pure, can be burned and is a useful constituent, while the ash is useless and remains behind after combustion. The ash consists of non-combustible earthy and mineral matters.

As Received, Dry Fuel, Combustible.—The published analyses are usually given for the condition of fuel "As received" containing its original moisture, for the "Dry Fuel" or "Moisture Free" state in which the moisture has been excluded, and for the "Combustible"

or moisture and ash-free form. "Combustible" is that portion which will burn and includes the volatile matters and fixed carbon, the moisture and ash being excluded.

Miscellaneous Prospecting

Many marshy tracts may be seen in passing through the country by railroad. A certain amount of miscellaneous prospecting may be done by studying these deposits from the train. It is comparatively easy to make observations and take notes concerning the physical features of the marshes and their surroundings in this way, such matters as slope of land, drainage, erosion, amount of water, nature of soils, vegetation, area, etc., being readily noted in passing.

This means of locating marshes may often be employed to advantage in preliminary prospecting work. Notes can be made concerning the principal characteristics and if these indicate that the marsh is worthy of a more detailed study, it can be examined more closely by a later visit.

Surface Vegetation as an Indication of Peat

The vegetation found upon peaty areas is described in detail for the various deposits discussed in subsequent pages. As will be seen, certain forms of plants are usually present where peat occurs and these are, therefore, a guide to peat deposits. A little experience will enable the prospector to judge to some extent the presence or absence of peat and, in some measure, the character of the same from the vegetation found upon the deposit. At the same time, the presence of typical peat forming plants does not always indicate the presence of peat and the only sure way of knowing definitely about the deposit is by digging samples from various places and depths in the marsh.

CHAPTER V

THE PEAT DEPOSITS OF WISCONSIN 1903 SURVEY

THE PEAT SURVEY OF 1903

The data concerning the peat deposits described in this chapter were collected in 1903 by A. L. Johnson and R. H. Hadfield who were at that time senior mechanical engineering students at the University of Wisconsin and used the subject, "An Investigation of the Peat Deposits in Wisconsin," for their graduating thesis. They were under the direction of Prof. A. W. Richter of the Experimental Engineering Department of the University. Their work consisted of examining a number of marshes, collecting samples and analyzing these samples in the University laboratories.

The author has abstracted and rearranged the data so as to conform to the other work given in Chapter VI.

Where the term, "The Peat Survey of 1903," has been used, it refers to the work grouped in this chapter. As will be seen, the marshes prospected in 1903 are all, with a few exceptions, located in the southern part of the state. A schedule of the localities visited, samples collected, etc., follows:

TABLE 11

SCHEDULE OF SAMPLES OBTAINED IN THE PEAT SURVEY OF 1903

Deposit No.	Sample Number	Location of Deposit	County	Page
1	1 to 5, inclusive..	$1\frac{1}{2}$ miles S. E. of Stoughton	Dane	83
2	1 to 5, inclusive..	$1\frac{1}{4}$ miles W. of Whitewater	Rock	85
3	1 to 3, inclusive..	On eastern outskirts of Whitewater.	Walworth	87
4	1 to 2, inclusive..	$4\frac{1}{2}$ miles N. E. of Whitewater	Jefferson	88
5	1 to 3, inclusive..	1 mile S. of Lake Beulah Station	Racine	89
6	1	$1\frac{1}{2}$ miles W. of Dousman	Waukesha	91
7	1	Lake Wingra Marsh, Madison	Dane	91
8	1 to 5, inclusive..	Sheboygan marsh, N. and E. of Glen Beulah	Sheboygan	91
9	1 to 6, inclusive..	2 miles S. of Medina. Rat River marsh	Winnebago	93
10	1 to 6, inclusive..	$3\frac{1}{2}$ miles S. of Eldorado, near Fond du Lac	Fond du Lac	96
11	1 to 5, inclusive..	N. End of Horicon marsh, 1-2 miles E. of Chester	Dodge	98
12	1 to 6, inclusive..	$\frac{3}{4}$ miles N. of Mendota	Dane	100
13	1 to 2, inclusive..	Markesan	Green Lake	102
14	1	Marshall	Dane	103
15	1 to 4, inclusive..	E. of Rhinelander	Oneida	104
16	1	1 mile N. W. of Camp Douglas	Juneau	106
17	1	3 miles N. W. of Babcock	Wood	106

In the following pages the peat deposits are described in their numerical order.

Stoughton Marsh—Deposit No. 1

This deposit is a moss growth 1½ miles southeast of Stoughton in Dane county. It lies between the Catfish River and the C. M. & St. P. Ry. tracks. The surrounding land is hilly and is under cultivation. The deposit has an area of 520 acres and is approximately over 9 feet deep.

The following samples were collected here:

SAMPLE 1

Location of Sample in Bed; near west shore.

Depth of Sample from Surface; 7 feet.

	As received	Dry Fuel	Combustible
Moisture, per cent	69.7		
Volatile Matter, per cent		63.3	71.5
Fixed Carbon, per cent		25.3	28.5
Ash, per cent		11.4	
B. T. U., per pound		9,320	10,500

SAMPLE 2.

Location of sample in bed: near west shore.

Depth of sample from surface: 9 feet.

	As Received	Dry Fuel	Combustible
Moisture, per cent	65.2		
Volatile Matter, per cent		63.1	72.0
Fixed Carbon, per cent		24.5	28.0
Ash, per cent		12.4	
B. T. U., per pound		8,980	10,260

SAMPLE 3.

Location of sample in bed: 50 ft. from west shore.

Depth of sample from surface: 4 ft.

	As Received	Dry Fuel	Combustible
Moisture, per cent	87.0	....	....
Volatile Matter, per cent	....	62.4	70.39
Fixed Carbon, per cent	....	26.5	29.8
Ash, per cent	....	11.1	....
B. T. U., per pound	....	8,929	10,000

SAMPLE 4.

Location of sample in bed: near center of marsh.

Depth of sample from surface: 3″ or 4″ from top.

	As Received	Dry Fuel	Combustible
Moisture, per cent	74.4	....	....
Volatile Matter, per cent	....	59.3	74.4
Fixed Carbon, per cent	....	20.5	25.7
Ash, per cent	....	20.2	....
B. T. U. per pound	....	6,190	7,760

SAMPLE 5.

Location of sample in bed: near center of marsh.

Depth of sample from surface: 9 ft.

	As Received	Dry Fuel	Combustible
Moisture, per cent	85.3	....	....
Volatile Matter, per cent	....	63.3	73.9
Fixed Carbon, per cent	....	23.6	26.1
Ash, per cent	....	13.1	....
B. T. U., per pound	....	8,570	9,880

WHITEWATER MARSH—DEPOSIT NO. 2

West of the center of Whitewater about 1¼ miles is a marsh belonging to the Whitewater Peat Co. The vegetation on the marsh consists principally of a moss growth. Most of the surrounding land is cultivated and consists of low rolling hills. In area the deposit is 640 acres while its depth is 9 feet. Five samples of peat from this deposit are given below. A factory for the manufacture of peat into briquettes is located here.

SAMPLE 1.

Location of sample in bed: 300 ft. west from factory

Depth of sample from surface: 9 ft.

	As Received	Dry Fuel	Combustible
Moisture, per cent	69.4	....	....
Volatile Matter, per cent	....	38.4	69.5
Fixed Carbon, per cent	....	16.9	30.6
Ash, per cent	....	44.7	....
B. T. U., per pound	....	6,040	10,900

Remarks: This sample was taken too near the bottom of the deposit and contains some clay and sand.

SAMPLE 2.

Location of sample in bed: 300 ft. west from factory.

Depth of sample from surface: 5.5 ft.

	As Received	Dry Fuel	Combustible
Moisture, per cent	85.5	....	....
Volatile Matter, per cent	....	60.4	68.5
Fixed Carbon, per cent	....	27.8	31.6
Ash, per cent	....	11.8	....
B. T. U., per pound	....	9,440	10,700

SAMPLE 3.

Location of sample in bed: 300 ft. west from factory.
Depth of sample from surface: 3 ft.

	As Received	Dry Fuel	Combustible
Moisture, per cent	82.8	....	....
Volatile Matter, per cent	....	58.2	68.7
Fixed Carbon, per cent	....	26.6	31.4
Ash, per cent	....	15.2	....
B. T. U., per pound	....	9,040	10,650

SAMPLE 4.

Location of sample in bed: From trench dug for commercial purposes.
Depth of trench: From 6 to 8 ft.

	As Received	Dry Fuel	Combustible
Moisture, per cent	33.4	....	....
Volatile Matter, per cent	....	57.4	69.4
Fixed Carbon, per cent	....	25.4	30.7
Ash, per cent	....	17.2	....
B. T. U., per pound	....	9,370	11,300

Remarks:—Sample was taken from some of the unground and artificially dried, not compressed, product at Whitewater factory. It had been standing for some months.

WESTPORT MARSH AT MENDOTA, DANE COUNTY

A typical meadow marsh. Most of the peat deposit is made up of grass and sedge remains. The growing marsh grasses are shown in the foreground. Farther back cat-tails may be seen. The Catfish River drains this marsh and may be seen in the background.

WESTPORT MARSH AT MENDOTA, DANE COUNTY

This marsh lies along the banks of the slowly moving Catfish or Yahara River. The narrow strip in the left of the picture, consisting of cat-tails, grasses and sedges, contains excellent thoroughly-decomposed peat which extends to a depth of nine feet in some places. Between the banks and the open water may be seen a variety of green, floating, pond-weed which completely covers the water. Tufts of wild rice and pond lilies may be seen in this zone also. This is a type of peat deposit which is common in southern Wisconsin.

SAMPLE 5.

Location of sample: Taken from trench dug for commercial purposes.

Depth of trench: From 6 to 8 ft.

	As Received	Dry Fuel	Combustible
Moisture, per cent	14.0		
Volatile Matter, per cent		59.7	67.0
Fixed Carbon, per cent		29.4	33.0
Ash, per cent		10.9	
B. T. U., per pound		8,600	9,695

Remarks:—This sample was taken from some of the compressed commercial product made in 1902 at the Whitewater factory. Said to have been stored in a rather damp place.

WHITEWATER MARSH—DEPOSIT NO. 3

This deposit is a tamarack swamp, with moss growth, located on the eastern outskirts of Whitewater, in Walworth County. The surrounding country is rolling. Most of the country is under cultivation with a small amount of standing timber making up the remainder. There are 200 acres of peat seven feet in depth.

SAMPLE 1

Location of sample: Near center of bed.

Depth of sample: 6 1-1 ft. from surface.

	As Received	Dry Fuel	Combustible
Moisture, per cent	83.0		
Volatile Matter, per cent		52.2	64.9
Fixed Carbon, per cent		28.3	35.2
Ash, per cent		19.5	
B. T. U., per pound		8,060	10,000

SAMPLE 2

Location of sample: Near center of bed.

Depth of sample: 5 ft. from surface.

	As Received	Dry Fuel	Combustible
Moisture, per cent	82.9	....	....
Volatile Matter, per cent	....	62.0	68.4
Fixed Carbon, per cent	....	28.7	31.6
Ash, per cent	....	9.3	....
B. T. U., per pound	....	8,370	9,250

SAMPLE 3

Location of sample: Near center of bed.

Depth of sample: 2 ft. from surface.

	As Received	Dry Fuel	Combustible
Moisture, per cent	80.7	....	....
Volatile Matter, per cent	....	57.2	68.0
Fixed Carbon, per cent	....	27.0	32.0
Ash, per cent	....	15.8	....
B. T. U., per pound	....	8,600	10,200

Whitewater Marsh—Deposit No. 4

A marsh consisting of a mixed moss and grass growth, known as the Scuppernong Marsh, is located 4½ miles northeast of Whitewater in Jefferson County. This deposit is located in a low area of about 20 square miles. Its depth is between 5 and 6 feet. The marsh receives its name from the fact that the Scuppernong River runs through it and during wet seasons the river floods the marsh.

SAMPLE 1

Location of sample: Half mile from east shore and 1 1-2 miles from west end.

Depth of sample: 6 ft. from surface.

	As Received	Dry Fuel	Combustible
Moisture, per cent	81.1		
Volatile Matter, per cent		55.7	69.0
Fixed Carbon, per cent		25.1	31.1
Ash, per cent		19.2	
B. T. U., per pound		7,920	9,800

SAMPLE 2

Location of sample: Half mile from east shore, 1 1-2 miles from west end.

Depth of sample: 3 1-2 ft. from surface.

	As Received	Dry Fuel	Combustible
Moisture, per cent	80.7		
Volatile Matter, per cent		53.1	62.3
Fixed Carbon, per cent		32.3	37.8
Ash, per cent		14.6	
B. T. U., per pound		8,490	9,900

Lake Beulah Marsh—Deposit No. 5

This deposit is located 1 mile south of Lake Beulah station, Racine County, on the east side of the railroad tracks. A moss growth with a little grass composes the principal vegetation of the marsh. The surrounding country is hilly and is very little cultivated. Small timber is found on the edge of the marsh. The deposit covers an area of 500 acres.

SAMPLE 1

Location of sample in bed: North-west end of marsh.

	As Received	Dry Fuel	Combustible
Moisture, per cent	58.5	....	....
Volatile Matter, per cent	....	58.5	67.3
Fixed Carbon, per cent	....	28.6	32.8
Ash, per cent	....	12.9	....
B. T. U., per pound	....	8,280	9,500

Remarks—Sample taken from some air dried, pulverized peat, taken out by P. J. Buckley, for experimental purposes. Had been piled in open air for five or six months and was covered with snow when the sample was taken.

SAMPLE 2

Location of sample in bed: North-west end of marsh.

	As Received	Dry Fuel	Combustible
Moisture, per cent	14.9	....	....
Volatile Matter, per cent	....	56.7	64.7
Fixed Carbon, per cent	....	30.9	35.3
Ash, per cent	....	12.4	....
B. T. U., per pound	....	8,870	10,100

Remarks:—Sample taken from some pulverized, dried peat, prepared by P. J. Buckley for experimental purposes. Dried artificially in open drier and stored in sheds on marsh.

SAMPLE 3

Location of sample: North-east end of marsh.
Depth of sample from surface: 7 ft.

	As Received	Dry Fuel	Combustible
Moisture, per cent	83.5	....	....
Volatile Matter, per cent	....	59.3	68.1
Fixed Carbon, per cent	....	27.5	31.9
Ash, per cent	....	13.2	....
B. T. U., per pound	....	8,870	10,200

Dousman Marsh—Deposit No. 6

A grass marsh, $1\frac{1}{2}$ miles west of Dousman, lies on either side of the tracks of the C. & N. W. Ry., in Waukesha County. The topography surrounding the marsh is rolling. In extent the marsh covers about 15 square miles. In the flat portion of the deposit the peat has a depth of 3 feet, while in the sink hole portion the bottom was not reached with the sounding tool.

The Bark river flows through this marsh. This deposit is very soft and not dense enough to be worked commercially. The peat is not well decomposed and is too soft to be taken up in blocks. A centrifugal pump would have to be used in gathering the peat. On account of the samples being so watery the sampler would not hold them. A sink hole, located in the marsh, was tested for depth and was found to be more than 15 feet deep.

On account of the liquid condition of the peat no samples were preserved for analysis.

Madison Marsh—Deposit No. 7

The Lake Wingra Marsh, at Madison, Dane County, was examined but the peat was not sufficiently decomposed and was too thin to be of much value. Large quantities of sand and dirt were found mixed with the peat. A sample was obtained from a depth of $2\frac{1}{2}$ feet at the east end of the lake, but no test was made of same

.

Glen Beulah Marsh—Deposit No. 8

In Sheboygan County, north and east of Glen Beulah, is the Sheboygan Marsh. The surrounding country is very hilly. In area the marsh covers about 15 square miles and its depth is 9 feet. The following samples were all taken near the "gravel road" which runs across the marsh north and south, just about dividing it. In ordinary seasons the marsh is fairly dry and much marsh hay is cut from it in the summer. One-third to one-half of the marsh is covered with 15-year old spruce, tamarack and pine. The Sheboygan River flows through the marsh. Marl underlies the deposit.

SAMPLE 1

Location of sample: 1-2 mile north of Frailey's farm.
Depth of sample from surface: 9 ft.

	As Received	Dry Fuel	Combustible
Moisture, per cent	88.2	......	......
Volatile Matter, per cent	......	64.5	69.0
Fixed Carbon, per cent	......	29.0	31.0
Ash, per cent	......	6.5	......
B. T. U., per pound	......	9,060	9,700

SAMPLE 2

Location of sample in bed: 1 mile north of Frailey's farm.
Depth of sample from surface: 8 feet.

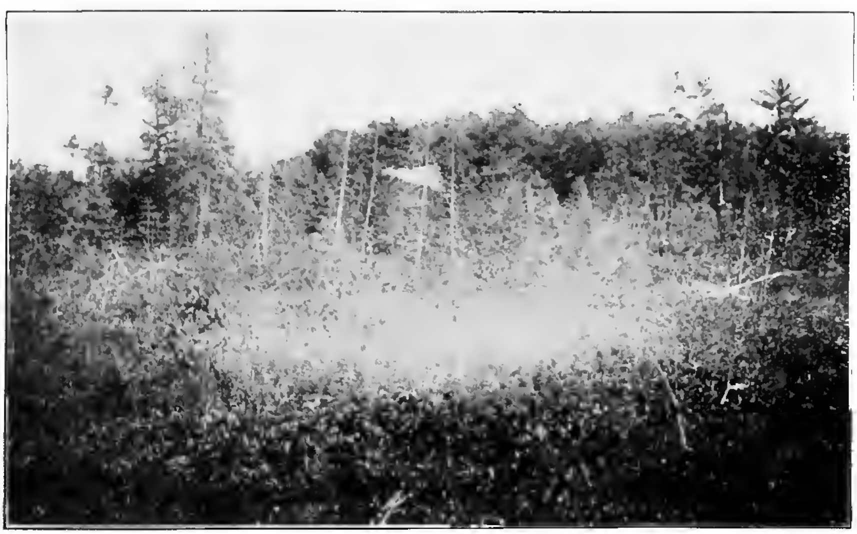
	As Received	Dry Fuel	Combustible
Moisture, per cent	89.4	......	......
Volatile Matter, per cent	......	68.7	72.9
Fixed Carbon, per cent	......	25.7	27.1
Ash, per cent	......	5.6	......
B. T. U., per pound	......	10,600	11,200

SAMPLE 3

Location of sample in bed: 1½ miles north of Frailey's farm, ½ mile east.
Depth of sample from surface: 9 feet.

	As Received	Dry Fuel	Combustible
Moisture, per cent	90.5	......	......
Volatile Matter, per cent	......	67.2	72.7
Fixed Carbon, per cent	......	25.3	27.3
Ash, per cent	......	7.5	......
B. T. U., per pound	......	9,500	10,300

MEADOW MARSH AT WAUPACA, WAUPACA COUNTY



SPHAGNUM BOG AT WAUPACA, WAUPACA COUNTY

SAMPLE 4

Location of sample in bed: ½ mile north of Frailey's farm.

Depth of sample from surface: 1½ feet.

	As Received	Dry Fuel	Combustible
Moisture, per cent	90.6		
Volatile Matter, per cent		63.8	72.1
Fixed Carbon, per cent		21.8	27.9
Ash, per cent		11.4	
B. T. U., per pound		8,500	9,600

SAMPLE 5

Location of sample in bed: 1½ miles north of Frailey's farm.

Depth of sample from surface: 1½ feet.

	As Received	Dry Fuel	Combustible
Moisture, per cent	89.4		
Volatile Matter, per cent		65.3	73.5
Fixed Carbon, per cent		23.6	26.5
Ash, per cent		11.1	
B. T. U., per pound		8,650	9,700

Medina Marsh—Deposit No. 9

This deposit is known as the Rat River Marsh and lies in Winnebago County, 2 miles south of Medina city. The vegetation consists of mixed grass and moss growth. A large part of the marsh is covered with 8 to 10-year old timber. In extent the marsh has an area of 10 square miles and its depth is from 6 to 14 feet, averaging about 12 feet deep.

This marsh is the source of the Rat River which empties into the Wolf River. Samples were taken south of the town of Medina and near the farm of Lee Running. The marsh has a clay bottom.

SAMPLE 1

Location of sample in bed: 1-8 mile south of Lee Running's farm.

Depth of sample from surafce: 1 1-2 feet.

	As Received	Dry Fuel	Combustible
Moisture, per cent	83.8	....	....
Volatile Matter, per cent	....	63.8	69.0
Fixed Carbon, per cent	....	28.6	31.0
Ash, per cent	....	7.6	....
B. T. U. , per pound	....	8,700	9,450

SAMPLE 2

Location ot sample in bed: 1-8 mile south of Lee Running's farm.

Depth of sample from surface: 10 feet.

	As Received	Dry Fuel	Combustible
Moisture, per cent	69.1	....	....
Volatile Matter, per cent	....	43.4	75.3
Fixed Carbon, per cent	....	14.2	24.7
Ash, per cent	....	42.4	....
B. T. U., per pound	....	3,700	6,300

Remarks:—This sample was taken too near the bottom and contained some clay and earthy matters.

SAMPLE 3

Location of sample: 1-4 mile south of Lee Running's farm.

Depth of sample from surface 2½ feet.

	As Received	Dry Fuel	Combustible
Moisture, per cent	88.8	....	....
Volatile Matter, per cent	....	59.8	67.1
Fixed Carbon, per cent	....	29.4	32.9
Ash, per cent	....	10.8	....
B. T. U., per pound	....	8,400	9,500

SAMPLE 4

Location of sample: 1-4 mile south of Lee Running's farm.

Depth of sample from surface: 3 feet.

	As Received	Dry Fuel	Combustible
Moisture, per cent	83.4		
Volatile Matter, per cent		61.7	67.2
Fixed Carbon, per cent		30.0	32.8
Ash, per cent		8.3	
B. T. U., per pound		9,800	10,600

SAMPLE 5

Location of sample: 1-4 mile south of Lee Running's farm.

	As Received	Dry Fuel	Combustible
Moisture, per cent	83.5		
Volatile Matter, per cent		56.2	65.5
Fixed Carbon, per cent		29.7	34.5
Ash, per cent		14.1	
B. T. U., per pound		8,600	9,900

SAMPLE 6

Location of sample: ½ mile south of Lee Running's farm.

	As Received	Dry Fuel	Combustible
Moisture, per cent	80.0		
Volatile Matter, per cent		62.6	76.5
Fixed Carbon, per cent		19.3	23.5
Ash, per cent		18.1	
B. T. U., per pound		7,300	8,900

ELDORADO MARSH—DEPOSIT NO. 10

A moss and grass growth mixed covers a deposit of peat $3\frac{1}{2}$ miles south of Eldorado station. This deposit lies in Fond du Lac County in a low and rolling stretch of country. There are 6 or 7 square miles of marsh containing peat to a depth of about 8 feet underlaid by a clay bottom.

Extensive work was done at this marsh in 1869 and the remains of two long ditches, from which peat was taken for commercial manufacture, can still be seen.

SAMPLE 1

Location of sample: 200 ft. from north shore, near old ditch.

Depth of sample from surface: 3 feet.

	As Received	Dry Fuel	Combustible
Moisture, per cent	83.1	....	....
Volatile Matter, per cent	....	61.8	69.9
Fixed Carbon, per cent	....	26.8	30.1
Ash, per cent	....	11.4	....
B. T. U., per pound	....	8,800	9,900

SAMPLE NO. 2

Location of sample: 1-4 mile south from north shore, east end.

Depth of sample from surface: 7 feet.

	As Received	Dry Fuel	Combustible
Moisture, per cent	81.4	....	....
Volatile Matter, per cent	....	60.6	71.7
Fixed Carbon, per cent	....	24.0	28.3
Ash, per cent	....	15.4	....
B. T. U., per pound	....	8,800	10,400

SAMPLE 3

Location of sample: ½ mile south from north shore, east end.

Depth of sample from surface: 8 feet.

	As Received	Dry Fuel	Combustible
Moisture, per cent	79.5		
Volatile Matter, per cent		43.7	59.5
Fixed Carbon, per cent		29.8	40.5
Ash, per cent		26.5	
B. T. U., per pound		4,800	6,600

SAMPLE 4

Location of sample: ½ mile south from north shore.

Depth of sample from surface: 3 feet.

	As Received	Dry Fuel	Combustible
Moisture, per cent	80.1		
Volatile Matter, per cent		55.4	66.9
Fixed Carbon, per cent		27.5	33.1
Ash, per cent		17.1	
B. T. U., per pound		6,900	8,300

SAMPLE 5

Location of sample: 1-4 mile south from north shore.

Depth of sample from surface: 7 feet.

	As Received	Dry Fuel	Combustible
Moisture, per cent	84.0		
Volatile Matter, per cent		61.1	68.0
Fixed Carbon, per cent		29.0	32.0
Ash, per cent		9.9	
B. T. U., per pound		8,700	9,600

SAMPLE 6

Location of sample: 3-4 mile south of north shore, center.

	As Received	Dry Fuel	Combustible
Moisture, per cent	88.9		
Volatile Matter, per cent		70.5	76.5
Fixed Carbon, per cent		21.8	23.5
Ash, per cent		7.7	
B. T. U., per pound		10,300	11,100

Chester Marsh—Deposit No. 11

From 1 to 2 miles east of Chester, in Dodge County, lies the Horicon Marsh. Grass grows in abundance and in dry summers it is cut for marsh hay. This deposit covers an area of 50 square miles or more, and has an average depth of 6 feet. The bottom of the marsh is a bed of clay.

SAMPLE 1

Location of sample: 1½ miles east of Chester.

Depth of sample from surface: 5 feet.

	As Received	Dry Fuel	Combustible
Moisture, per cent	79.0		
Volatile Matter, per cent		55.3	66.2
Fixed Carbon, per cent		28.4	33.8
Ash, per cent		16.3	
B. T. U., per pound		7,300	8,770

SAMPLE 2

Location of sample in bed: ¼ mile from west shore in north-east end of marsh.

Depth of sample from surface: 3 feet.

	As Received	Dry Fuel	Combustible
Moisture, per cent	77.7		
Volatile Matter, per cent		48.0	66.4
Fixed Carbon, per cent		23.3	33.6
Ash, per cent		28.7	
B. T. U., per pound		7,600	10,600

SAMPLE 3

Location of sample: 1¼ mile from west shore in north-east end of marsh.

Depth of sample from surface: 3 feet.

	As Received	Dry Fuel	Combustible
Moisture, per cent	78.6		
Volatile Matter, per cent		52.7	67.5
Fixed Carbon, per cent		25.1	32.5
Ash, per cent		21.9	
B. T. U., per pound		7,100	9,100

SAMPLE 4

Location of sample: 1½ miles from west shore in north-east end of marsh.

Depth of sample from surface: 3½ feet.

	As Received	Dry Fuel	Combustible
Moisture, per cent	77.9		
Volatile Matter, per cent		47.9	66.9
Fixed Carbon, per cent		23.8	33.1
Ash, per cent		28.3	
B. T. U., per pound		6,700	9,400

SAMPLE 5

	As Received	Dry Fuel	Combustible
Moisture, per cent	82.0	....	....
Volatile Matter, per cent	....	58.1	76.6
Fixed Carbon, per cent	....	17.8	23.4
Ash, per cent	....	24.1	....
B. T. U., per pound	....	6,870	9,000

Mendota Marsh—Deposit No. 12

Three-quarters of a mile north of Mendota, in Dane County, is a grass marsh which covers an area of from 2 to 3 square miles and has a deposit of peat about 10 feet in depth. A large part of this marsh lies on the north shore of Lake Mendota and is very wet.

SAMPLE 1

Location of sample in bed: 100 feet west of railroad tracks in center of marsh.

Depth of sample from surface: 5 feet.

	As Received	Dry Fuel	Combustible
Moisture, per cent	86.4	....	....
Volatile Matter, per cent	....	61.1	72.8
Fixed Carbon, per cent	....	25.1	27.2
Ash, per cent	....	10.8	....
B. T. U., per pound	....	8,700	9,800

EXPOSED PEAT SECTION AT WAUPACA, WAUPACA COUNTY

This is a section, about 6 feet deep, of a typical sphagnum and tamarack bog, which was first cut off and then forced up by the settling of a railroad bed laid across the bog. A typical "sink hole." The peat is brown and fibrous.

EXPOSED PEAT SECTION AT WAUPACA, WAUPACA COUNTY

Here is shown an exposed section of black, thorougbly-decomposed peat. The upper layer of growing vegetation was removed to uncover the lower layer of peat.

SAMPLE 2

Location of sample: 600 ft. west of railroad tracks in center of marsh.
Depth of sample from surface: 5½ feet.

	As Received	Dry Fuel	Combustible
Moisture, per cent	86.6		
Volatile Matter, per cent		60.1	70.4
Fixed Carbon, per cent		25.5	29.6
Ash, per cent		14.4	
B. T. U., per pound		8,400	9,800

SAMPLE 3

Location of sample: 1,000 ft. east of railroad tracks in center of marsh.
Depth of sample from surface: 5 feet.

	As Received	Dry Fuel	Combustible
Moisture, per cent	86.5		
Volatile Matter, per cent		57.7	68.6
Fixed Carbon, per cent		26.4	31.4
Ash, per cent		15.9	
B. T. U., per pound		8,100	9,600

SAMPLE 4

Location of sample: 1,200 ft. west of railroad tracks in center of marsh.
Depth of sample from surface: 9 feet.

	As Received	Dry Fuel	Combustible
Moisture, per cent	85.8		
Volatile Matter, per cent		56.9	68.7
Fixed Carbon, per cent		25.9	31.3
Ash, per cent		17.2	
B. T. U., per pound		7,800	9,500

SAMPLE 5

Location of sample: ¼ mile east of railroad tracks.

Depth of sample in bed: 9 feet from surface.

	As Received	Dry Fuel	Combustible
Moisture, per cent	85.4	....	....
Volatile Matter, per cent	....	54.0	63.0
Fixed Carbon, per cent	....	31.8	37.0
Ash, per cent	....	14.2	....
B. T. U., per pound	....	7,800	9,200

SAMPLE 6

Location of sample: ¼ mile east of railroad tracks.

Depth of sample: Surface.

	As Received	Dry Fuel	Combustible
Moisture, per cent	88.6	....	....
Volatile Matter, per cent	....	63.1	69.6
Fixed Carbon, per cent	....	27.6	30.4
Ash, per cent	....	9.3	....
B. T. U., per pound	....	9,200	10,100

Markesan Marsh—Deposit No. 13

This deposit is located in Green Lake county, near Markesan. It consists of a mixed moss and grass growth. The samples taken here were sent in by a party at Markesan who wished the deposit tested. In depth the peat is reported as 12 feet.

SAMPLE 1

Location of sample: Middle of Marsh.

Depth of sample: 2 feet from surface.

	As Received	Dry Fuel	Combustible
Moisture, per cent	85.1		
Volatile Matter, per cent		60.8	67.1
Fixed Carbon, per cent		30.1	32.9
Ash, per cent		9.1	
B. T. U., per pound		9,500	10,400

SAMPLE 2

Location of sample: South side of marsh.

Depth of sample: 12 feet from surface.

	As Received	Dry Fuel	Combustible
Moisture, per cent	67.0		
Volatile Matter, per cent		45.9	
Fixed Carbon, per cent		7.1	
Ash, per cent		47.0	
B. T. U., per pound			

Remarks:—This sample was taken too near the bottom of the marsh and as the high percentage of ash rendered it of no value commercially it was not tested for heating value.

MARSHALL MARSH—DEPOSIT NO. 14

A mixed moss and grass growth near Marshall, in Dane county, has peat in it. Prof. Baldwin, of Marshall, sent in a sample to be tested. This sample was taken from the surface and gave the following analysis:

SAMPLE 1

	As Received	Dry Fuel	Combustible
Moisture, per cent	18.6	....	....
Volatile Matter, per cent	....	60.9	68.8
Fixed Carbon, per cent	....	27.9	31.4
Ash, per cent	....	11.2	....
B. T. U., per pound	....	9,000	10,200

RHINELANDER MARSH—DEPOSIT NO. 15

Just east of the city of Rhinelander in Oneida county is a peat deposit made up of a very dense growth of moss. This deposit covers an area of 2 square miles and has a depth of 6 feet.

SAMPLE 1

Location of sample: 300 feet east of town.

Depth of sample: 2½ feet from surface.

	As Received	Dry Fuel	Combustible
Moisture, per cent	89.3	....	....
Volatile Matter, per cent	....	66.2	70.1
Fixed Carbon, per cent	....	28.3	29.9
Ash, per cent	....	5.5	....
B. T. U., per pound	....	10,600	11,300

SAMPLE 2

Location of sample: 300 feet east of the town.

Depth of sample from surface: 4 feet.

	As Received	Dry Fuel	Combustible
Moisture, per cent	91.4		
Volatile Matter, per cent		66.3	70.9
Fixed Carbon, per cent		27.3	29.1
Ash, per cent		6.4	
B. T U., per pound		9,600	10,300

SAMPLE 3

Location of sample: 1,000 feet east of town.

Depth of sample from surface: 5 feet.

	As Received	Dry Fuel	Combustible
Moisture, per cent	89.4		
Volatile Matter, per cent		71.3	75.8
Fixed Carbon, per cent		22.8	24.2
Ash, per cent		5.9	
B. T. U., per pound		9,200	9,800

SAMPLE 4

Location of sample: 1,000 feet east of town.

Depth of sample from surface: 4 feet.

	As Received	Dry Fuel	Combustible
Moisture, per cent	90.7		
Volatile Matter, per cent		66.0	69.9
Fixed Carbon, per cent		28.5	30.1
Ash, per cent		5.5	
B. T. U., per pound		9,960	10,500

Camp Douglas Marsh—Deposit No. 16

One mile northwest of Camp Douglas, in Juneau county, is a grass marsh. Surrounding the marsh is a country which is very rocky on the south and east and rolling on the north and west. In the marsh are standing rocks. This deposit covers from 3 to 4 square miles, and contains sandy fuel to a depth of from 1 to 2 feet. On account of the sandy soil surrounding the deposit and the consequent large amount of sand in the peat, this marsh is of practically no commercial value. In the summer time the marsh is impassable on account of the water it contains.

Babcock Marsh—Deposit No. 17

Three miles northwest of Babcock, in Wood county, is a bog consisting of a growth of grass and moss. The surrounding country is low and the soil is very sandy. The peat here is very watery and thin and is not sufficiently decomposed. All of the deposits are of the same nature and too sandy to be of value commercially.

TAMARACK SWAMP AT WAUPACA, WAUPACA COUNTY

In this picture is shown a deposit of peat which is covered with tamarack and other swamp conifers. At the right may be seen the remains of a "land plaster" factory in which the marl, underlying this peat deposit, was formerly manufactured into a fertilizing material known as "land plaster" in this vicinity.

MIXED SPHAGNUM AND TAMARACK DEPOSIT AT WAUPACA, WAUPACA COUNTY

This deposit represents a type of sphagnum bog often called a "sink hole," owing to the fact that it appears to have no bottom. The railroad crossing this deposit required many carloads of gravel, earth and other debris to make a firm foundation. In fact, the road bed continues to settle from time to time and must be repaired constantly. This deposit is over 20 feet deep, but its real depth was not determined.

CHAPTER VI

THE PEAT DEPOSITS OF WISCONSIN

1908 SURVEY

The Peat Survey of 1908

The work done in collecting and testing the peat deposits described in this chapter will be referred to as "The Peat Survey of 1908". Such deposits as are embraced in this survey were prospected during the summer of 1908 by the writer, who spent two months in the field prospecting the deposits, collecting samples and sending them in for analysis.

Through arrangements made by Prof. Chas. A. Davis, U. S. Peat Expert, the samples collected in the field by the Wisconsin Geological and Natural History Survey were sent to the United States Geological Survey Fuel Testing Station, at Pittsburgh, where they were analysed under the direction of Dr. F. M. Stanton.

The results of these tests were utilized in an extended investigation, carried out by the United States Geological Survey, concerning the peat deposits of the United States as well as by the Wisconsin Geological and Natural History Survey for this bulletin.

Most of these deposits are located in the northern part of the state. The localities examined, numbers of samples collected, etc., are shown in the following schedule:

Table 12

Schedule of Samples Obtained in the Peat Survey of 1908

Deposit No.	Bottle or Sack	Location of Deposit	County	Page
301	Sack	Yahara River Bog, N. W. of Mendota at Brictson's Landing	Dane	110
301	Bottle	Yahara River Bog, N. W. of Mendota at Brictson's Landing	Dane	110
302	Sack	University Bay Marsh, W. of Madison, University Drive	Dane	111
302	Bottle	University Bay Marsh, W. of Madison, University Drive	Dane	111
303 A	Sack	Remains of Manufactured Peat from Mill of Dr. C. A. Beebe, Fond du Lac	Fond du Lac	114

Deposit No.	Bottle or Sack	Location of Deposit	County	Page
303 B	Sack......	From marsh of Dr. C. A. Beebe, Fond du Lac, Raw Peat	Fond du Lac........	113
303 B	Bottle...	From marsh of Dr. C. A. Beebe, Fond du Lac, Raw Peat	Fond du Lac........	
304	Sack......	½ mile N. of Waupaca	Waupaca.............	115
304	Bottle...	½ mile N. of Waupaca	Waupaca.............	115
305	Sack......	2½ miles N. of Waupaca	Waupaca.............	116
305	Bottle...	2½ miles N. of Waupaca	Waupaca.............	117
306	Sack......	8 miles N. E. of Kiel, Manitowoc River Marsh. Fresh sample	Manitowoc	118
306	Bottle...	8 miles N. E. of Kiel, Manitowoc River Marsh. Fresh sample	Manitowoc	118
307	Sack......	8 miles N. E. of Kiel, Manitowoc River Marsh. Air dried sample dug by R. Thiessen	Manitowoc	118
308	Sack......	Marsh 1 mile S. W. of Kiel	Manitowoc	119
308	Bottle...	Marsh 1 mile S. W. of Kiel	Manitowoc	119
309	Sack......	Sheboygan Marsh, 6 miles S. of Kiel	Manitowoc	120
309	Bottle ..	Sheboygan Marsh, 6 miles S. of Kiel	Manitowoc	120
310	Sack......	6 to 7 miles E. of Bloomer, Meadow Marsh....	Chippewa.............	121
310	Bottle...	6 to 7 miles E. of Bloomer, Meadow Marsh....	Chippewa.............	122
311	Sack......	6 to 7 miles E. of Bloomer, Cassandra Bog......	Chippewa.............	122
311	Bottle...	6 to 7 miles E. of Bloomer, Cassandra Bog......	Chippewa.............	123
312	Sack......	2 miles W. of Ashland on Lake Superior	Ashland................	123
312	Bottle..	2 miles W. of Ashland on Lake Superior	Ashland................	124
313	Sack......	2 miles W. of Hayward, Tamarack Swamp......	Sawyer.................	125
313	Bottle...	2 miles W. of Hayward, Tamarack swamp......	Sawyer.................	125
314	Sack......	3 miles W. of Hayward, Cassandra Bog	Sawyer.................	126
314	Bottle...	3 miles W. of Hayward, Cassandra Bog	Sawyer.................	126
315	Sack.....	2½ miles N. of New Auburn, Meadow Marsh	Barron.................	127
315	Bottle..	2½ miles N. of New Auburn, Meadow Marsh	Barron.................	127
316	Sack......	S. W. of Cameron, Bennett's Cranberry Marsh	Barron.................	128
316	Bottle...	S. W. of Cameron, Bennett's Cranberry Marsh	Barron.................	128
317	Sack......	¼ mile W. of Ladysmith	Gates...................	130
317	Bottle...	¼ mile W. of Ladysmith	Gates...................	130
318	Sack......	⅛ mile S. E. of Heafford Junction	Oneida.................	131
318	Bottle...	⅛ mile S. E. of Heafford Junction	Oneida.................	131
319	Sack......	2 miles S. of Minocqua, Tamarack Swamp......	Vilas.....................	132
319	Bottle...	2 miles S. of Minocqua, Tamarack Swamp......	Vilas	132
320	Sack......	¼ mile S. W. of Minocqua. Cattail Marsh	Vilas.....................	133
320	Bottle...	¼ mile S. W. of Minocqua, Cattail Marsh	Vilas.....................	133
321	Sack......	8 miles N. E. of Lac du Flambeau	Vilas.....................	134
321	Bottle...	8 miles N. E. of Lac du Flambeau	Vilas.....................	134
322	Sack......	1 mile S. W. of Powell, Tamarack Swamp........	Vilas.....................	135
322	Bottle...	1 mile S. W. of Powell, Tamarack Swamp........	Vilas.....................	135
323	Sack......	2 miles N. of Glidden, Cassandra Bog	Ashland................	136
323	Bottle...	2 miles N. of Glidden, Cassandra Bog	Ashland................	136
324	Sack......	½ mile N. of Park Falls	Price.....................	137
324	Bottle...	½ mile N. of Park Falls	Price.....................	137
325	Sack......	½ mile N. of Kewaunee	Kewaunee...........	138
325	Bottle...	½ mile N. of Kewaunee	Kewaunee...........	138
326	Sack......	5 miles S. W. of Algoma	Kewaunee...........	139
326	Bottle...	5 miles S. W. of Algoma	Kewaunee...........	139
327	Sack......	4 miles S. of Sturgeon Bay	Door.....................	140
327	Bottle...	4 miles S. ot Sturgeon Bay	Door.....................	140
328	Sack......	2 miles S. W. of Peshtigo	Marinette.............	140
329	Sack......	2 miles W. of Pembine	Marinette.............	141
329	Bottle...	2 miles W. of Pembine	Marinette.............	141
330	Sack......	1 mile E. of Gagen	Oneida.................	142
330	Bottle...	1 mile E. of Gagen	Oneida.................	142
331	Sack......	2 miles S. of Eagle River	Vilas.....................	143
331	Bottle...	2 miles S. of Eagle River	Vilas.....................	143
332	Bottle...	2 miles S. of Antigo	Langlade.............	143
333	Sack......	1 mile N. of Mountain	Oconto.................	144
333	Bottle...	1 mile N. of Mountain	Oconto.................	144

In the following pages the peat deposits and samples are described in their numerical order.

MARSHES NEAR MADISON

Yahara River Marsh

This marsh lies about 2 miles northwest of Mendota. The Yahara river flows into Lake Mendota from the north. At the mouth of the river and following along its banks for several miles inland is a considerable area of marsh land (500 acres). The C. & N. W. Ry. and a wagon road cross the river about $\frac{3}{4}$ miles from the lake end of the marsh. About $\frac{1}{8}$ mile out in the bay and extending across the bay from Farwell's Point to near Fox's Bluff is a bar or old lake shore which became submerged due to the placing of a dam at the Yahara river outlet of Lake Mendota. This caused a rise of 6 or 7 feet in the lake level.

At the water's edge are found various kinds of aquatic plants, among them wild celery, white and yellow pond lilies, bull weeds and pickerel weeds. On the swampy area are marsh blue bells, marsh grasses of several varieties, wide and narrow bladed sedges, calamus, arrow head, bulrushes, cat-tails and wild rice.

A sample of peat (301) was taken here. It is of a black, thoroughly decomposed variety, having bits of fibrous material throughout. The deposit is what may be called a double deck deposit, being formed of a lower layer and an upper layer separated by water. The lower or bed layer is probably the original peat, formed before the lake level was raised, while the upper bed is more recent and has been formed since.

The upper layer consists of about 2 feet of apparently excellent peat. Below this the material is very soft and watery for about 3 feet. Then there is a 3 to 4 foot layer of peat below the watery layer. Below this are found blue clay, sand and marl at a depth of 7 feet.

Below is shown an analysis of Sample 301, collected from this marsh.

PEAT SAMPLE SACK 301

	Air Dried	As Received	Dry Fuel
Moisture, per cent	9.26	65.07	....
Volatile Matter, per cent	47.18	18.16	51.99
Fixed Carbon, per cent	17.89	6.89	19.73
Ash, per cent	25.67	9.88	28.28
B. T. U., per pound	6,250	2,407	6,890
Sulphur, per cent	.42	.16	.45

Air drying loss: 61.50 per cent.

PEAT SAMPLE BOTTLE 301

	Aid Dried	As Received
Moisture, per cent	8.60	83.55

Air-drying loss: 82 per cent.

University Bay Marsh

The University Bay marsh is located about ½ mile west of the Main Hall of the University and is upon University land. It covers an area of about 100 acres. To the south of the marsh is a line of the C. M. & St. P. Ry. Running along the northern shore is the University Drive. This drive is built upon what appears to be a shore line ridge formed by ice shoves from Lake Mendota. About 200 feet from shore, and in the bay, is a bar extending from the University Point to Picnic Point. This represents the remains of the old lake shore which existed before the placing of a dam at the Yahara river outlet caused a flooding of this marsh.

The principal vegetation consists of arrow head, bulrushes, marsh blue-bell, small amounts of moss, various marsh grasses and sedges with both wide and narrow blades. There are practically no large plants or trees. At the water's edge the vegetation consists of the same materials. In addition, yellow and white pond lilies and several other varieties of water plants are found in the water at the lake edge of the marsh.

Sample 302, consists of an average of several samples collected at various points along the University Drive, crossing the marsh. It has a black, thoroughly decomposed appearance and contains fragments of roots, sedge, and seeds of plants. The peat bed has an average depth of 6 feet. Below the peat is a bed of clay.

The number of tons of dry peat available in this deposit is estimated as follows:

100 acres x 6 feet deep = 600 acre feet.

600 acre feet x 200 tons per acre foot = 120,000 tons.

An analysis of the sample gave the following:

PEAT SAMPLE SACK 302

	Air Dried	As Received	Dry Fuel
Moisture, per cent	8.99	71.33	....
Volatile Matter, per cent	50.82	16.01	55.84
Fixed Carbon, per cent	21.42	6.75	23.55
Ash, per cent	18.77	5.91	20.61
B. T. U., per pound	6,943	2,187	7,628
Sulphur, per cent	.38	.12	.42

Air drying loss: 68.50 per cent.

The convenient location and close proximity of this marsh to the University makes this peat deposit available for experimental work with peat in the Engineering Laboratories.

PEAT SAMPLE BOTTLE 302

	Air Dried
Moisture, per cent	6.92

Air drying loss: 84.30 per cent.

Other Marshes in the Madison District

There are several other marshy tracts in the vicinity of Madison covered with the usual marsh vegetation but some of these are valueless as peat deposits. Southeast of Mendota 1½ miles, on the C. &

N. W. Ry., is an area of about 80 acres of marsh formed by Lake Mendota, between Maple Bluff and Mendota Park. The principal vegetation consists of grasses, sedges, arrow head and bulrushes. An exploration showed about 2 feet of turf above a sandy bottom, making this of no value.

A canal, connecting Lakes Monona and Wingra, passes through the Dane County Fair Grounds. These grounds and the land adjoining the canal are marshy with the typical marsh vegetation growing upon them but there is no peat. The turf has a sandy clay bottom at a depth of 2 feet.

The marshland, lying below the Black Bridge and along the Yahara river between Lakes Monona and Waubesa, is not peaty. Sand is found at a depth of 2 to 3 feet. Cattails, bulrushes, slender and wide bladed sedges and grasses are plentiful.

Marshes Near Fond du Lac

The country in the vicinity of Fond du Lac, Oshkosh, Neenah-Menasha, Appleton and Kaukauna is of a red clay soil variety and the many marshy tracts caused by Lake Winnebago and the Fox river do not contain peat. The slope of the land is gradual toward Lake Winnebago and not until the high land to the west of the lake is reached is the country suitably rough for the formation of peat.

About 7 miles to the west of the lake the country begins to take on a morainal character and marshy tracts containing good peat are found. West of Fond du Lac are several peat marshes of large size containing good peat suitable for commercial use. At various times some of these marshes have been utilized and peat has been manufactured and used for fuel. Here may be found the peat briquetting plant of the Lamartine Peat, Light & Power Co., which, however, is not in operation at the present time.

The marsh of the Lamartine Peat, Light & Power Co., is located 7 miles due west of Fond du Lac. It covers an area of perhaps 800 acres. It is a shallow depression having good, thoroughly decomposed peat to a depth of 7 feet. The peat has decomposed fibrous remains of marsh plants throughout and seeds of aquatic plants are present. Sample 303 B was taken near the center of the marsh. Sedges, grasses, rushes, arrow head plant and ferns are the principal plants growing here. Near the center of the marsh are patches of bushes, but otherwise the marsh has no large vegetation. Consequently, the peat can be taken out easily. However, the fact that no railroads are near this deposit reduces its value to some extent.

In general, this deposit and several others in the same neighborhood have a large amount of an excellent grade of peat in them. There are about 800 acres of peat in this vicinity averaging 7 feet in depth. Assuming 200 tons of finished peat per acre-foot there are 1,120,000 tons of peat in these deposits.

Sample 303 B was taken from the marsh in its original or moist condition. Its analysis follows:

PEAT SAMPLE SACK 303 B

	Air Dried	As Received	Dry Fuel
Moisture, per cent	11.99	76.94	....
Volatile Matter, per cent	51.03	13.37	57.98
Fixed Carbon, per cent	21.75	5.70	24.72
Ash, per cent	15.23	3.99	17.30
B. T. U., per pound	7,169	1,879	8,149
Sulphur, per cent	.66	.17	.74

Air drying loss: 73.80 per cent.

The ultimate analysis of this sample shows it to be made up thus:

PEAT SAMPLE SACK 303 B

	Air Dried	As Received	Dry Fuel
B. T. U., per pound		1,730	....
Carbon, per cent	41.50	10.87	47.14
Hydrogen, per cent	5.22	9.57	1.42
Oxygen, per cent	34.81	74.72	27.45
Nitrogen, per cent	2.58	.68	2.95
Sulphur, per cent	.66	.17	.74
Ash, per cent	15.23	3.99	17.30

PEAT SAMPLE BOTTLE 303 B

	Air Dried	As Received
Moisture, per cent	7.72	86.16

Air drying loss, 85 per cent.

Some of the manufactured peat was found in the abandoned factory. A sample of this was taken from the bins. This sample, 303 A, gave the following analysis:

PEAT SAMPLE SACK 303 A

	Air Dried	As Received	Dry Fuel
Moisture, per cent	9.95	15.89	....
Volatile Matter, per cent	48.14	44.96	53.45
Fixed Carbon, per cent	25.14	23.49	27.93
Ash, per cent	16.77	15.66	18.62
B. T. U., per pound	7,468	6,975	8,293
Sulphur, per cent	.79	.74	.88

Air drying loss: 6.6 per cent.

Waupaca Marshes

The southern half of Waupaca county has many peat marshes. These are in the vicinity of Waupaca and Weyauwega and are reached by the Chicago division of the "Soo" railway. From Medina Junction to Amherst Junction, the railroad crosses several of these marshes.

There are two large marshes near Waupaca. One of these lies northwest, the other, northeast of the city. The marsh about ½ mile north of Waupaca was examined and found to cover an area of about 1,500 acres. It is of the meadow grass and wide and shallow basin types. A small pond of water is located in the center of the marsh and receives the principal drainage water. A new road, the Waupaca & Green Bay Ry. passes across the marsh making it easily accessible.

The vegetation found here is composed of grass, sedge, marsh blue-bell, moss and bullrushes. There are also some tamaracks along the border of the marsh.

Soundings made at several points showed excellent peat of a black, tough, thoroughly decomposed variety, the deposit being of unequal depth. It was found to be 6 feet deep near the southern side while a little north of center it reached a depth of 17 feet.

Peat sample 304 taken from several places in the marsh and representing an average gave the following analysis:

SWAMP NEAR BRADLEY, LINCOLN COUNTY

SWAMP NEAR BRADLEY, LINCOLN COUNTY

PEAT SAMPLE SACK 304

	Air Dried	As Received	Dry Fuel
Moisture, per cent	6.95	25.00	...
Volatile Matter, per cent	54.23	43.71	58.29
Fixed Carbon, per cent	23.44	18.89	25.18
Ash, per cent	15.38	12.40	16.53
B. T. U., per pound	7,614	6,136	8,181
Sulphur, per cent	.13	.30	.10

Air drying loss: 19.40 per cent.

PEAT SAMPLE BOTTLE 304

	Air Dried	As Received
Moisture, per cent	6.90	86.59

Air drying loss: 85.60 per cent.

Using the usual figure of 200 tons of finished peat per acre-foot and assuming the depth to average 7 feet, the amount of peat fuel available in this marsh may be taken roughly as:

1,500 x 200 x 7 or 2,100,000 tons.

The close proximity of this deposit to the city of Waupaca, the good quality of the peat, and its large amount, suggest that this marsh may be of considerable value as a source of fuel.

There are other deposits of a similar character not far from Waupaca. These have not been prospected except that they were observed from the train in passing through the country.

In addition to the sedge marshes there are located near Waupaca several small built-up cassandra, moss and tamarack bogs. Near Scandinavia on both the Waupaca & Green Bay Ry., and the Green Bay & Western Ry., are several of these bogs, which, on account of having given much trouble to the railroad foundations passing over them, are commonly called "sink holes." There are about 200 acres of this type of bog in this vicinity.

One of these bogs, about 2½ miles north of Waupaca and on the Waupaca & Green Bay Ry., was prospected. It covers an area of about 60 acres. The slope of the sides of the basin forming this bog

is about 45° and, consequently, though the area is small, the bog is deep. The depth was not finally determined but it is more than 20 feet. Upon the surface of the bog the following vegetation is found: Tamarack, spruce, cassandra, andromeda, cranberry, pitcher plant, arrow plant, several types of moss, among them sphagnum in large quantities, sedges of various kinds and several varieties of marsh grass. Much water is present in this marsh and the soft, built-up character of the moss makes the surface springy and sponge-like.

There is a layer of surface vegetation to a depth of about 2 feet. Below this there is about 2 feet of sphagnum moss. At 5 feet the deposit begins to consist of brown, decomposed, fibrous material containing seeds of plants. This fibrous material extends down about 9 feet, becoming darker and more dense at a depth of about 12 feet. From 12 feet down there is a grayish material of a peaty, decomposed character and this extends to a depth greater than 20 feet.

Sample 305 was taken from this bog and its analysis showed it to have the following composition:

PEAT SAMPLE SACK 305

	Air Dried	As Received	Dry Fuel
Moisture, per cent	6.62	18.76	....
Volatile Matter, per cent	55.31	48.12	59.23
Fixed Carbon, per cent	13.63	11.86	14.60
Ash, per cent	24.44	21.26	26.17
B. T. U., per pound	6,970	6,064	7,465

Air drying loss: 13.00 per cent.

An ultimate analysis of this sample gave the following:

PEAT SAMPLE SACK 305

	Air Dried	As Received	Dry Fuel
B. T. U., per pound	....	5,686	....
Carbon, per cent	37.60	42.71	40.26
Hydrogen, per cent	5.35	6.09	4.94
Oxygen, per cent	29.32	27.07	25.10
Nitrogen, per cent	2.64	2.30	2.83
Sulphur, per cent	.65	.57	.70
Ash, per cent	24.44	21.26	26.17

PEAT SAMPLE BOTTLE 305

	Air Dried	As Received
Moisture, per cent	7.64	95.29

Air drying loss: 94.90 per cent.

Manitowoc County Marshes

Several large peat areas are found in Manitowoc county. They are principally located in a zone running east and west through the center of the county. These areas are of the swamp type upon which are found tamaracks, cedars, spruce and other swamp vegetation. Upon some of the high points in the swamp are pines, maples and poplars.

Manitowoc Marsh

One of the most important of these swamps is known as the "Manitowoc Swamp." It is located about 8 miles north of Kiel and about 6 miles northeast of New Holstein. A branch of the Manitowoc river flows through the swamp. The area covered by this marsh is somewhere in the vicinity of 10,000 acres.

The roots of the trees penetrate the swamp to a depth not to exceed 2 feet. The peat found below these roots runs to a depth of 8 feet, and below 8 feet marl is encountered. The peat is of a black, dense, compact and thoroughly decomposed variety. Considerable water is found below 2 feet from the surface.

Sample 306 was taken at a point about ½ mile from the border of the swamp and from several points and at various depths. It may be called an average and representative sample. Below is the analysis.

PEAT SAMPLE SACK 306

	Air Dried	As Received	Dry Fuel
Moisture, per cent	7.70	22.84	....
Volatile Matter, per cent	48.38	40.45	52.42
Fixed Carbon, per cent	16.00	13.37	17.33
Ash, per cent	27.92	23.34	30.25
B. T. U., per pound	6,107	5,107	6,619
Sulphur, per cent	1.51	1.26	1.63

Air drying loss: 16.40 per cent.

PEAT SAMPLE BOTTLE 306

	Air Dried	As Received
Moisture, per cent	7.44	84.82

Air drying loss: 83.60 per cent.

A place was found in the swamp where a hole had been dug about a year ago by Reinhardt Thiessen of Kiel. This had a depth of 8 feet and was dug with a post-hole digger. Most of the peat so removed was left near the hole and was air-dried. Sample 307 of this material was taken for analysis.

PEAT SAMPLE SACK 307

	Air Dried	As Received	Dry Fuel
Moisture, per cent	6.82	33.28	....
Volatile Matter, per cent	52.30	37.45	56.13
Fixed Carbon, per cent	21.42	15.34	22.99
Ash, per cent	19.46	13.93	20.88
B. T. U., per pound	7,256	5,195	7,787
Sulphur, per cent	1.51	1.08	1.62

Air drying loss: 28.40 per cent.

About 2 feet of the top of the marsh would have to be cleared of trees and roots before the peat deposited here could be taken out. There would be left about 6 feet of excellent black and thoroughly decomposed peat. If the area of the marsh be assumed as 7,500 acres and the useful depth of peat be taken as 6 feet, then the approximate number of tons of commercial peat in the swamp would be roughly,

7,500 x 6 x 200 or 9,000,000 tons.

Kiel Marsh

Just 1 mile southwest of Kiel is a tract of marsh land which is of the meadow and sedge type principally, and which covers an area of 600 acres. Sample 308, taken here, gave the analysis shown:

PEAT SAMPLE SACK 308

	Air Dried	As Received	Dry Fuel
Moisture, per cent	7.79	26.60	....
Volatile Matter, per cent	53.04	42.22	57.52
Fixed Carbon, per cent	20.85	16.60	22.62
Ash, per cent	18.32	14.58	19.86
B. T. U., per pound	7,119	5,666	7,720
Sulphur, per cent	.82	.65	.89

Air drying loss: 20.10 per cent.

PEAT SAMPLE BOTTLE 308

	Air Dried	As Received
Moisture, per cent	9.25	88.11

Air drying loss: 86.90 per cent.

This marsh is principally of the sedge type and was quite dry at the time it was prospected. The sample, taken near the road crossing the marsh, indicated peat to a depth of 6 feet underlaid by marl. A calculation of the tons of peat available in this deposit gives the following:

600 x 6 x 200 or 720,000 tons.

Sheboygan Marsh

Another large marsh lies about 6 miles south of Kiel. It is known in that vicinity by the name of Sheboygan marsh. Its area is about 5,500 acres and its depth is from 4 to 4½ feet, and rests upon a bed of marl. On account of an exceedingly dry summer the marsh was quite dry at the time it was visited. It may be described as a largely open sedge type of marsh with a heavy growth of tamarack in the upper end.

The tons of peat are roughly:

5,500 x 4½ x 200 or 4,950,000 tons.

Peat sample 309 from this marsh gave the following analysis:

PEAT SAMPLE SACK 309

	Air Dried	As Received	Dry Fuel
Moisture, per cent	8.22	20.43	....
Volatile Matter, per cent	58.07	50.35	63.28
Fixed Carbon, per cent	23.21	20.12	25.28
Ash, per cent	10.50	9.10	11.44
B. T. U., per pound	8,032	6,964	8,753
Sulphur, per cent	.64	.55	.69

PEAT SAMPLE BOTTLE 309

	Air Dried	As Received
Moisture, per cent	7.79	91.06

Air drying loss: 90.3 per cent.

In the vicinity of Chilton, New Holstein and Elkhart Lake, there are many smaller tamarack swamps and sedge marshes like those described above, but they are smaller and less important.

Marshes at Bloomer

The principal peat deposits in Chippewa county are located from 6 to 8 miles north, northeast and east of Bloomer. There are several large burned over tamarack swamps in this district.

The swamps located about 7 miles east of Bloomer were examined. Three principal types were found, viz; the meadow, the tamarack and mixed cassandra and sphagnum moss types. There are from 4,000 to 5,000 acres of these types of bogs in this vicinity.

A large, fairly-clear meadow marsh, now used for hay, has about 2,000 acres. It is about half clear and half has growing tamaracks and other conifers upon it. Many stumps remain, indicating that it is a burned over marsh. There is also some young hardwood timber growing but largely of a brushy character. The principal small plants are smart weed, golden rod, bulrushes, fern, moss, sedges and grasses.

The marsh is partially drained by a stream which passes through its center. Sample 310 was taken near the middle of the marsh and along the road passing across it. Peat is found to a depth of 3 ft. Then there is 3 feet of marl, below which is brown sand. The peat, which is black and thoroughly decomposed, contains the remains of grasses, sedges and seeds of various kinds. A sample indicates the following analysis.

PEAT SAMPLE SACK 310

	Air Dried	As Received	Dry Fuel
Moisture, per cent	11.76	76.09	....
Volatile Matter, per cent	41.80	11.33	47.39
Fixed Carbon, per cent	15.30	4.14	17.31
Ash, per cent	31.14	8.44	35.30
B. T. U., per pound	5,503	1,490	6,233
Sulphur, per cent	.28	.08	.33

Air drying loss: 72.9 per cent.

PEAT SAMPLE BOTTLE 310

	Air Dried	As Received
Moisture, per cent	9.15	81.92

Air drying loss: 80.10 per cent.

The amount of peat available in these deposits is roughly:
2,000 x 3 x 200 or 1,200,000 tons.

Sample 311 was taken from a marsh which, from the slope of the surrounding high land, indicated a deep and narrow basin. It is typical of many small marshes in this area. The vegetation consists of hardwood saplings around the border, grass, sedges, cassandra, sphagnum and tamaracks in the center. Burned pine and tamarack stumps are present.

The peat obtained here is brown and quite fibrous. It is browner and more fibrous near the top than it is below, becoming denser, blacker and more decomposed near the bottom. The deposit extends to a depth of 6 feet. Below this is marl.

An analysis of this sample is given below.

PEAT SAMPLE SACK 311

	Air Dried	As Received	Dry Fuel
Moisture, per cent	10.35	78.30	....
Volatile Matter, per cent	49.26	11.92	54.93
Fixed Carbon, per cent	24.74	5.99	27.60
Ash, per cent	15.65	3.79	17.47
B. T. U., per pound	7,929	1,919	8,842
Sulphur, per cent	.21	.05	.23

Air drying loss: 75.80 per cent.

BUILT-UP SPHAGNUM BOG AT BRADLEY, LINCOLN COUNTY

This is a type of shallow basin deposit which is still in the early stages of formation. Evidently a small lake is gradually being filled and covered by the annual growth and advance of the peat forming vegetation. The growth started at the outside edge of the basin and now covers all but a small portion in the center. In time the plant mat will grow out to the center, thus completely covering the area which now shows water.

SWAMP AT BRADLEY, LINCOLN COUNTY

Here is illustrated a type of swamp very common in the northern part of Wisconsin. It represents waste land very desolate in appearance. The trees standing on the marsh are all dead and resemble large fish-poles stuck into the deposit.

PEAT SAMPLE BOTTLE 311

	Air Dried	As Received
Moisture, per cent	7.67	83.57

Air drying loss: 82.20 per cent.

Marsh Near Ashland

About 2 miles west of Ashland and on the shore of Lake Superior is a marshy tract covering an area of perhaps 80 acres. Lake Superior bounds the marsh on the north side. The southern side of the marsh is bounded by a ridge of land covered with hardwood timber and the C. & N. W. Ry. runs along this ridge. A lumber yard is located in the northwest section of the marsh.

The vegetation consists of sedges, rushes, arrow leaf, ferns and cattails. Along the border and near the high land are maple saplings and some tamaracks of small size. There is a large amount of standing water and the vegetation is extensive.

Sample No. 312, taken at this point, shows the peat to be of the brown decomposed variety to a depth of 8 feet. Below this is brown clay. At a point in the marsh, near its center and along the railroad track running to the lumber piles, sand is encountered at 2 feet. The samples contain wood and decomposed sedge and grass remains.

Sample 312, collected here gave the following analysis:

PEAT SAMPLE SACK 312

	Air Dried	As Received	Dry Fuel
Moisture, per cent	6.82	49.03	....
Volatile Matter, per cent	26.69	14.60	28.64
Fixed Carbon, per cent	6.38	3.49	6.85
Ash, per cent	60.11	32.88	64.51
B. T. U., per pound	2,984	1,633	3,202
Sulphur, per cent	.24	.13	.26

Air drying loss: 45.30 per cent.

PEAT SAMPLE BOTTLE 312

	Air Dried	As Received	Dry Fuel
Moisture, per cent	4.57	63.07	....
Volatile Matter, per cent	22.60	8.75	23.69
Fixed Carbon, per cent	5.64	2.18	5.91
Ash, per cent	67.19	26.00	70.40
B. T. U., per pound	....	....	....
Sulphur, per cent	.18	.07	.19

Air drying loss: 61.30 per cent.

Hayward Marshes.

Sawyer county has a great many marshy tracts of fair size. Few of these, however, are accessible by railroad. The marshes consist of tamarack swamps, cassandra and sphagnum bogs and meadow marshes.

Some of the swamps in the vicinity of Hayward were prospected. About 2 miles west of Hayward on the main wagon road is a small but deep tamarack swamp of the deep basin type. It is covered with a thick growth of tamarack and other swamp conifers together, with sedge, grass, moss, cassandra and fern. The area of this marsh is about 40 acres.

Sample 313, taken at this place, showed the following characteristics. It was of a dark-brown, fibrous character, not thoroughly decomposed, containing sedge, grass and similar remains of swamp plants. The peat is quite dense and hard to a depth of 8 feet. From this depth down to 16 feet it is much softer and watery. Thus, the total depth of this deposit at the point examined is 16 feet. Underlying the peat is a black clay.

Assuming 14 feet of useful peat, the tons of dry fuel may be estimated as:

40 x 14 x 200 or 112,000 tons.

The analysis of this sample shows the following:

PEAT SAMPLE SACK 313

	Air Dried	As Received	Dry Fuel
Moisture, per cent	10.21	18.29	....
Volatile Matter, per cent	50.77	46.20	56.54
Fixed Carbon, per cent	25.06	22.81	27.92
Ash, per cent	13.96	12.70	15.54
B. T. U., per pound	7,866	7,159	8,761
Sulphur, per cent	.26	.24	.29

Air drying loss: 9.00 per cent.

An ultimate analysis gives the following:

PEAT SAMPLE SACK 313

	Air Dried	As Received	Dry Fuel
B. T. U., per pound	....	6,777	....
Carbon, per cent	45.79	41.67	51.00
Hydrogen, per cent	5.36	5.88	4.71
Oxygen, per cent	32.91	37.94	26.51
Nitrogen, per cent	1.72	1.57	1.92
Sulphur, per cent	.26	.24	.29
Ash, per cent	13.96	12.70	15.54

PEAT SAMPLE BOTTLE 313

	Air Dried	As Received
Moisture, per cent	6.66	91.41

Air drying loss: 90.80 per cent.

A large bog, 3 miles west of Hayward, was also prospected. It is located on the main road going from Hayward west, and close to the western boundary of the county.

The bog is oval in contour and fills up a deep depression. It covers about 200 acres and is made up principally of cassandra and sphagnum moss. The principal vegetation observed here consists of cassandra, andromeda, sphagnum moss and two other varieties of moss, pitcher plant, Labrador tea, grasses, sedges and young tamaracks. Along the border of the marsh and on the higher land are young pines, poplars, hardwood saplings and underbrush.

Sample 314, taken here, shows the peat to have the usual characteristics common to this type of bog. The top layer, about 6 feet in thickness, has the mossy, brown, fibrous character. It is not well decomposed. This layer is soft and spongy and contains some water. At 6 feet the deposit changes to a black, fibrous peat containing plant remains. Sand forms the bottom of this bog at a depth of 10 feet.

Following is a test of this sample.

PEAT SAMPLE SACK 314

	Air Dried	As Received	Dry Fuel
Moisture, per cent	7.71	18.14	....
Volatile Matter, per cent	51.13	45.35	55.40
Fixed Carbon, per cent	20.07	17.80	21.74
Ash, per cent	21.09	18.71	22.86
B. T. U., per pound	7,411	6,574	8,026
Sulphur, per cent	.39	.35	.43

Air drying loss: 11.30 per cent.

PEAT SAMPLE BOTTLE 314

	Air Dried	As Received
Moisture, per cent	3.93	91.45

Air drying loss: 91.10 per cent.

A meadow type of marsh about 2 miles north of Hayward and along the tracks of the C. St. P. M. & O. Ry. was examined. It had most of the usual peat marsh vegetation but a sounding showed sand at a depth of 1½ feet.

Marsh near New Auburn

A meadow marsh about 2½ miles north of New Auburn was prospected. This marsh is crossed by the C. St. P. M. & O. Ry. It covers an area of 1,000 acres and is of the flat basin type. Grasses, sedges, ferns and golden rod make up most of the vegetation. Burned stumps are found throughout the marsh.

Sample 315, taken here, showed the following characteristics:

Surface to 2 feet, muck and roots of plants
2 feet to 4 feet, brown, fibrous peat, compact
4 feet to 7 feet, brown, fibrous peat, soft and watery
7 feet to 8 feet, black decomposed peat
8 feet, sand.

PEAT SAMPLE SACK 315

	Air Dried	As Received	Dry Fuel
Moisture, per cent	7.66	12.18	....
Volatile Matter, per cent	53.55	50.93	57.99
Fixed Carbon, per cent	25.48	24.23	27.59
Ash, per cent	13.31	12.66	14.42
B. T. U., per pound	8,222	7,819	8,905
Sulphur, per cent	.20	.19	.22

Air drying loss: 4.90 per cent.

PEAT SAMPLE BOTTLE 315

	Air Dried	As Received
Moisture, per cent	4.95	92.87

Air drying loss: 92.50 per cent.

About 2 miles southeast of New Auburn there is a burned over shallow basin covered with stumps, sedge, grass and rushes. Its area is 300 acres and it is apparently of the same variety as the marsh just north of New Auburn.

Assuming the useful depth of peat in these two deposits to be 6 feet, then the amount of available material would be:

1,300 x 6 x 200 or 1,560,000 tons.

Cameron Marsh and Other Marshes in Barron County

In the southeast quarter of Barron County are located several marshes. Along the C. St. P. M. & O. Ry., about 6 miles south of Chetek, is a shallow meadow marsh covering about 400 acres and of the same general character as the marsh at New Auburn, about 3 miles away. About 3 miles southeast of Chetek is a 300 acre area of the same type covered with arrow plant, cattail, rushes, sedge, grass and golden rod. Tamarack is found in spots and burned stumps are present. Near the center of the marsh is a patch of hardwood brush.

At Cameron is a marsh known as Bennett's Cranberry Marsh which covers about 500 acres. Its depth is approximately 14 feet. The peat obtained is of the brown fibrous kind, not thoroughly decomposed and containing plant remains. The vegetation upon the surface is composed of grass, sedges, ferns and cranberries. At present the marsh is being prepared for cranberry culture.

Sample 316 was obtained from this marsh and came from about 3 feet below the surface. Its analysis is given below.

PEAT SAMPLE SACK 316

	Air Dried	As Received	Dry Fuel
Moisture, per cent	5.21	14.03	....
Volatile Matter, per cent	60.08	54.49	63.38
Fixed Carbon, per cent	26.78	24.29	28.26
Ash, per cent	7.93	7.19	8.36
B. T. U., per pound	8,716	7,906	9,196
Sulphur, per cent	.28	.25	.29

Air drying loss: 9.30 per cent.

PEAT SAMPLE BOTTLE 316

	Air Dried	As Received
Moisture, per cent	7.22	91.19

Air drying loss: 90.50 per cent.

The amounts of peat available in this deposit may be estimated to be:

500 x 14 x 200 or 1,400,000 tons.

MARSHES AT LADYSMITH

Rusk county, formerly called Gates county, has a number of marshes. There is no particular kind predominant but all the varieties are met. None of these marshes are very large, practically none of them exceeding 150 acres. The meadow, cassandra and tamarack types are all found in this vicinity. The M. St. P. & S. Ste. M. Ry. crosses the county from east to west and passes over these marshes.

The following notes taken in passing through this region indicate the character of these marshes: Two miles west of Lehigh are 150 acres of mixed meadow and tamarack marsh, stumpy and of the shallow basin type. Two miles east of Lehigh, is a 60 acre tract of the same kind containing cassandra and cranberry in addition to stumps, sedge and young tamaracks. Between Lehigh and Weyerhauser, there are many small marshes and swamps. A one-acre cassandra bog is located about ½ mile west of Apollonia. Just near Apollonia are small sedge, cattail and tamarack areas.

A marsh ¼ mile southeast of Ladysmith, covering about 40 acres, was prospected and may be taken as an example of the marshes found in this region. The railroad passes along the northern side of the marsh. There are small patches of open water in various parts of the marsh and these contain pond lilies and other aquatic plants. Burned stumps are distributed throughout. The vegetation consists of wide and narrow blade sedges, grasses, several varieties of moss, cattails, arrow leaf, patches of cassandra, andromeda, and sphagnum. At several points in the marsh are clusters of young poplars. In the center is a small island upon which a cluster of white pines is growing. At the border of the marsh are willows, white pines, poplars and blackberry bushes.

Sample 317 shows the peat to be brown and fibrous, not much decomposed. There are roots, woody particles and sedge remains in the sample. The deposit was found to be as follows:

Surface ½ ft. to 1 ft. roots of growing plants.
1—3½ ft., brown, fibrous peat.
3½—4 ft., black clay.
4 ft., sand.

PEAT SAMPLE SACK 317

	Air Dried	As Received	Dry Fuel
Moisture, per cent	3.85	11.35	....
Volatile Matter, per cent	54.00	49.79	56.16
Fixed Carbon, per cent	20.98	19.34	21.82
Ash, per cent	21.17	19.52	22.02
B. T. U., per pound	7,646	7,051	7,952
Sulphur, per cent	.24	.22	.25

Air drying loss: 7.80 per cent.

PEAT SAMPLE BOTTLE 317

	Air Dried	As Received
Moisture, per cent	5.31	89.11

Air drying loss: 88.50 per cent.

Heafford Junction Marsh

About ½ mile southeast of Heafford Junction is a cassandra bog of the deep basin type covering an area of 80 acres. A lake lies to the east of the bog. The vegetation consists of sedge, cotton grass, pitcher plant, andromeda, cassandra, sphagnum and other mosses and young tamaracks. At the border of the marsh are large ferns, poplars, pines and maples.

A sounding of the bog indicated that the deposit was made up in the following way:

Surface—1 ft., vegetation
1 ft.—6 ft., brown fibrous material, containing remains of vegetation; seeds, roots, leaves
6 ft.—14 ft., similar material, very wet
14 ft.—16 ft., dark brown fibrous material, containing roots, stalks, etc.
16 ft.—18 ft., black, thoroughly decomposed peat
18 ft.—20 ft., sandy peat
20 ft.—sand bottom

Sample 318 was collected at this marsh and analysed thus:

PEAT SAMPLE SACK 318

	Air Dried	As Received	Dry Fuel
Moisture, per cent	4.07	13.76	....
Volatile Matter, per cent	53.63	48.21	55.90
Fixed Carbon, per cent	20.44	18.38	21.31
Ash, per cent	21.86	19.65	22.79
B. T. U., per pound	7,722	6,943	8,051
Sulphur, per cent	.23	.21	.24

Air drying loss: 10.10 per cent.

PEAT SAMPLE BOTTLE 318

	Air Dried	As Received
Moisture, per cent	5.08	94.02

Air drying loss: 93.70 per cent.

Bogs at Minocqua

Two bogs near Minocqua were examined. The first of these, a tamarack swamp, is located 2 miles south of the city of Minocqua and is crossed by the main line of the C. M. & St. P. Ry. It covers an area of about 40 acres, is of the deep basin type, with sides sloping at an angle of 45 degrees.

The vegetation here consists of small and large tamaracks and spruce trees together with the smaller plants like cassandra, andromeda, Labrador tea, sphagnum moss and cranberry.

A section of the deposit, as revealed by soundings, is about as below:

Surface—1 ft., vegetation and roots.
1 ft.—3 ft., brown, fibrous peat, with rooty material, fairly dry, dense and compact peat.
3 ft.—6 ft., almost black, thoroughly decomposed peat.
6 ft.—sandy clay.

This sample gave the following test:

PEAT SAMPLE SACK 319

	Air Dried	As Received	Dry Fuel
Moisture, per cent	5.72	19.96	....
Volatile Matter, per cent	50.08	42.52	53.12
Fixed Carbon, per cent	20.82	17.67	22.08
Ash, per cent	23.38	19.85	24.80
B. T. U., per pound	7,456	6,331	7,909
Sulphur, per cent	.28	.24	.30

Air drying loss: 15.10 per cent.

PEAT SAMPLE BOTTLE 319

	Air Dried	As Received
Moisture, per cent	4.12	83.89

Air drying loss: 83.20 per cent.

A second marsh of the open type covers an area of about 80 acres and is located ¼ mile south of Minocqua. The C. M. & St. P. Ry. also crosses this marsh. Standing water may be seen at various places, and at the edge of the marsh are cattails. There is a lake of some size to the northeast. In addition to the cattails, the vegetation consists of sedge, grass, ferns and small amounts of cassandra.

The make-up of the deposit may be seen from the sounding given below.

Surface—1 ft., roots of growing plants.
1 ft.—3 ft., brown fibrous, loose roots and stalks.
3 ft.—6 ft., brown, fibrous, denser roots and stalks.
6 ft.—10 ft., mostly watery, brown fibrous material.
10 ft.—12 ft., denser and compacter brown, fibrous material.
12 ft.—15 ft., gray, thoroughly decomposed peaty material, containing seeds and plant remains.
15 ft.—16 ft., gray and soft material containing sand.
16 ft.—sand.

The test of this sample is as below:

PEAT SAMPLE SACK 320

	Air Dried	As Received	Dry Fuel	Combustible
Moisture, per cent	4.58	13.36	....	....
Volatile Matter, per cent	51.92	47.14	54.41	73.40
Fixed Carbon, per cent	18.82	17.09	19.72	26.60
Ash, per cent	24.68	22.41	25.87	....
B. T. U., per pound	7,236	6,570	7,583	10,229
Sulphur, per cent	.50	.45	.52	.70

Air drying loss: 9.20 per cent.

PEAT SAMPLE BOTTLE 320

	Air Dried	As Received
Moisture, per cent	4.36	92.83

Air drying loss: 92.50 per cent.

Lac du Flambeau Marsh

A marsh on the Lac du Flambeau Indian Reservation, about 8 miles northeast of Lac du Flambeau station, covers an area of about 15,000 acres. It is of the shallow, meadow type and at many points it has open water. The predominating vegetation consists of marsh grasses and sedges with young tamaracks, principally dead, throughout. Many burned stumps are present.

A sounding gave the following section:

Surface—½ ft., turf consisting of mosses, marsh grasses and roots

½ ft.—4 ft., black, thoroughly decomposed peat, containing roots

4 ft.—sand

The amount of peat available may be computed as :

15,000 x 4 x 200 or 12,000,000 tons.

Sample 321, collected here, has the following analysis.

PEAT SAMPLE SACK 321

	Air Dried	As Received	Dry Fuel
Moisture, per cent	2.68	13.19	....
Volatile Matter, per cent	53.52	47.47	54.99
Fixed Carbon, per cent	22.84	20.37	23.47
Ash, per cent	20.96	18.70	21.54
B. T. U., per pound	8,417	7,508	8,649
Sulphur, per cent	.16	.14	.16

Air drying loss: 10.80 per cent.

PEAT SAMPLE BOTTLE 321

	Air Dried	As Received
Moisture, per cent	5.02	84.52

Air drying loss: 83.70 per cent.

Powell Swamp

A tamarack and cedar swamp, about ¾ miles southwest of Powell, covers an area of 100 acres. It is densely wooded with tamarack, spruce, cedar, and an occasional poplar. The smaller vegetation is composed of Labrador tea, sphagnum, cassandra and fern.

The swamp is sectioned about as follows:

Surface—½ ft., growing plants and roots
½ ft.—3 ft., black, thoroughly decomposed peat
3 ft.—5 ft.,brown, thoroughly decomposed peat, containing woody material, quite wet
5 ft.—8 ft., denser and dryer brown peat, with woody material
8 ft.—Sand and small blue pebbles

PEAT SAMPLE SACK 322

	Air Dried	As Received	Dry Fuel
Moisture, per cent	6.56	17.21	....
Volatile Matter, per cent	53.04	46.99	56.76
Fixed Carbon, per cent	25.32	22.41	27.10
Ash, per cent	15.08	13.36	16.14
B. T. U., per pound	7,627	6,757	8,161
Sulphur, per cent	.89	.79	.95

Air drying loss: 11.40 per cent.

PEAT SAMPLE BOTTLE 322

	Air Dried	As Received
Moisture, per cent	6.29	88.29

Air drying loss: 87.50 per cent.

Glidden Bog

Two miles north of Glidden is a 300 acre mixed sphagnum cassandra and tamarack built up bog of the deep basin type. The Chicago Division of the "Soo" Ry. crosses this bog. Cattails, cassandra, sedge, cranberry, sphagnum, ferns and cotton grass are found here.

A section of the marsh showed it to be made up thus:

Surface—1½ ft., roots of growing plants, with much water
1½ ft.—6 ft., brown, fibrous peat, containing roots and stalks of decayed plants
6 ft.—12 ft., same, much water
12 ft.—13 ft., denser layer of brown peat, with plant remains containing seeds
13 ft.—14 ft., gray peat, decomposed and slippery
14 ft.—gray sand

PEAT SAMPLE SACK 323

	Air Dried	As Received	Dry Fuel
Moisture, per cent	4.62	13.20	....
Volatile Matter, per cent	58.33	58.08	61.15
Fixed Carbon, per cent	25.76	23.45	27.02
Ash, per cent	11.29	10.27	11.83
B. T. U., per pound	8,723	7,938	9,146
Sulphur, per cent	.22	.20	.23

Air drying loss: 9.00 per cent.

PEAT SAMPLE BOTTLE 323

	Air Dried	As Received
Moisture, per cent	6.33	92.32

Air drying loss: 91.80 per cent.

Park Falls Swamp

Around about Park Falls there are many small cedar, spruce and tamarack swamps. One of these was prospected. It is located ½ mile north of Park Falls, has an area of 60 acres, and is of the shallow basin type. The "Soo" Ry., crossing the swamp, divides it into two parts. That portion lying southeast of the railway is covered with sedge, grass, cattail, cassandra, andromeda, cotton grass, sphagnum, labrador tea and cranberry growths. Northwest of the tracks is a dense growth of almost virgin cedar, spruce and tamarack timber and balsam, ferns and sphagnum moss are also present. This portion of the marsh is built up as follows:

Surface—1 ft., roots of growing vegetation

1 ft.—3 ft., dense, dry, black, thoroughly decomposed peat, containing particles of wood.

3 ft.—3½ ft., brown, fibrous; looks like sedge remains

3½ ft.—5 ft., soft black peat

5 ft.—white sand

Sample 324 was taken from this swamp.

SPHAGNUM BOG AT BRADLEY, LINCOLN COUNTY

A built-up sphagnum bog covered with cassandra and the remains of dead conifers. Living conifers are seen at the borders of the bog. This is a type of peat deposit characteristic of northern Wisconsin and is made up principally of sphagnum moss, alive at the top and dead below.

MARSH AT WEYERHAUSER, RUSK COUNTY

Showing the grassy growth upon a deposit which was once covered with swamp conifers and later burned over. Trunks of burned trees are scattered throughout the deposit. Some of these remain standing while others have fallen. Also, burned stumps may be seen throughout the marsh.

PEAT SAMPLE SACK 324

	Air Dried	As Received	Dry Fuel
Moisture, per cent	3.99	11.67	
Volatile Matter, per cent	42.81	39.39	44.59
Fixed Carbon, per cent	18.95	17.43	19.74
Ash, per cent	34.25	31.51	35.67
B. T. U., per pound	6,291	5,787	6,552
Sulphur, per cent	.30	.28	.32

Air drying loss: 8.00 per cent.

PEAT SAMPLE BOTTLE 321

	Air Dried	As Received
Moisture, per cent	5.63	72.73

Air drying loss: 71.10 per cent.

Kewaunee Marsh

At the northeastern edge of the city of Kewaunee, and lying between two hills, is an 800-acre meadow marsh. It is crossed by a spur track of the Green Bay & Western Ry. A stream, passing through the center of the marsh on its way to Lake Michigan, drains most of the marsh and keeps it free from standing water.

The following vegetation is found: Moss, sedge, grass, fern, yellow flower resembling golden rod, marsh daisies and a purple flower. At the northwest border of the marsh is a clump of tamaracks. Stumps are plentiful.

A section of the marsh shows these characteristics.

Surface—1½ ft., black muck
1½ ft.—5½ ft., brown, fibrous, together with black peat
5½ ft.—6 ft., decomposed black peat
6 ft.—18 ft., soft marl
18 ft.—20 ft., gray clay

Sample 325 was taken here and gives the following analysis:

PEAT SAMPLE SACK 325

	Air Dried	As Received	Dry Fuel
Moisture, per cent	8.96	14.51	....
Volatile Matter, per cent	53.94	50.65	59.25
Fixed Carbon, per cent	23.60	22.16	25.92
Ash, per cent	13.50	12.68	14.83
B. T. U., per pound	7,290	6,845	8,006
Sulphur, per cent	.47	.44	.51

Air drying loss: 6.10 per cent.

PEAT SAMPLE BOTTLE 325

	Air Dried	As Received
Moisture, per cent	7.88	87.85

Air drying loss: 86.70 per cent.

Algoma Deposits

There are few peat deposits of importance at Algoma. Northeast of the city and near the railroad track is a marsh drained by a river emptying into Lake Michigan. This marsh was found to have about 1½ feet of thoroughly decomposed, black muck and peat underlaid with blue clay. No samples were collected because the deposit is too shallow to be of importance.

Another deposit, about 30 acres, lies 5 miles southwest of Algoma. It is a cedar and tamarack swamp in which ferns, sphagnum moss, cedar and tamarack are growing. Sample 326, taken here, showed the following:

Surface—1 ft., black, decomposed peat
1 ft.—2 ft., brown, fibrous peat
2 ft.—3 ft., black peat
3 ft.—marl and sand

PEAT SAMPLE SACK 326

	Air Dried	As Received	Dry Fuel
Moisture, per cent	7.51	10.75	....
Volatile Matter, per cent	38.52	37.17	41.65
Fixed Carbon, per cent	15.19	14.66	16.42
Ash, per cent	38.78	37.42	41.93
B. T. U., per pound	5,445	5,254	5,886
Sulphur, per cent	.26	.25	.28

Air drying loss: 3.50 per cent.

PEAT SAMPLE BOTTLE 326

	Air Dried	As Received
Moisture, per cent	7.63	70.07

Air drying loss: 67.60 per cent.

Sturgeon Bay Bog

The Green Bay & Western Ry. crosses a cranberry marsh about 4 miles south of Sturgeon Bay. In extent the marsh covers about 150 acres.

At the time of prospecting the marsh was burning and the dry vegetation had been pretty well burned off. The peat itself was on fire. In places, however, cassandra, tamarack, labrador tea, cranberry, andromeda, cotton grass, sphagnum and other mosses were present. There were also many burned stumps of trees. A section is as follows:

Surface—5 ft., brown, fibrous decayed plant material. Dry.
5 ft.—10 ft., brown, fibrous decayed plant material. Wet.
10 ft.—14 ft., decomposed grayish peat, containing seeds
14 ft.—blue clay

PEAT SAMPLE SACK 327

	Air Dried	As Received	Dry Fuel
Moisture, per cent	9.01	14.74	....
Volatile Matter, per cent	54.73	51.28	60.15
Fixed Carbon, per cent	16.20	15.18	17.80
Ash, per cent	20.06	18.80	22.05
B. T. U., per pound	7,186	6,734	7,898
Sulphur, per cent	.77	.72	.84

Air drying loss: 6.30 per cent.

PEAT SAMPLE BOTTLE 327

	Air Dried	As Received
Moisture, per cent	8.77	92.15

Air drying loss: 91.40 per cent.

Peshtigo Marsh

The C. & N. W. Ry. crosses a 500-acre meadow marsh about 2 miles south of Peshtigo. It is covered with cattail, grass, wide sedge and fern. The marsh has many burned stumps. At the time of visit the marsh was very dry and burning. Forest fires were raging round about the marsh and prospecting was done under difficulties.

At the point examined there was 2 feet of black peat, below which was sand.

PEAT SAMPLE SACK 328

	Air Dried	As Received	Dry Fuel
Moisture, per cent	5.07	76.36	....
Volatile Matter, per cent	43.29	10.78	45.60
Fixed Carbon, per cent	18.69	4.66	19.71
Ash, per cent	32.95	8.20	34.69
B. T. U., per pound	6,012	1,498	6,334
Sulphur, per cent	.66	.16	.68

Air drying loss: 75.10 per cent.

Pembine Marsh

Two miles west of Pembine on the M. St. P. & S. Ste. M. Ry., is an 80-acre cedar and tamarack swamp covered by a dense growth. Vegetation consisting of cedar, tamarack, sphagnum, balsam, labrador tea and moss abounds here. A deposit of peat, 6 feet deep, consisting of brown fibrous material containing decayed vegetation and seeds of plants, is found here. Beneath the peat is a sandy bottom.

PEAT SAMPLE SACK 329

	Air Dried	As Received	Dry Fuel
Moisture, per cent	9.25	15.42	....
Volatile Matter, per cent	50.60	47.16	55.75
Fixed Carbon, per cent	23.15	21.58	25.52
Ash, per cent	17.00	15.84	18.73
B. T. U., per pound	7,112	6,628	7,835
Sulphur, per cent	1.51	1.41	1.67

Air drying loss: 6.80 per cent.

An ultimate analysis of this sample shows:

PEAT SAMPLE SACK 329

	Air Dried	As Received	Dry Fuel
B. T. U., per pound	....	6,435	....
Carbon, per cent	42.51	39.62	46.84
Hydrogen, per cent	5.10	5.51	4.49
Oxygen, per cent	32.32	36.17	26.56
Nitrogen, per cent	1.56	1.45	1.71
Sulphur, per cent	1.51	1.41	1.67
Ash, per cent	17.00	15.84	18.73

PEAT SAMPLE BOTTLE 329

	Air Dried	As Received
Moisture, per cent	6.80	83.97

Air drying loss: 82.80 per cent.

Marsh at Gagen

Two hundred acres of cranberry marsh lie southeast of Gagen, a junction point of the "Soo" Ry. and the C. & N. W. Ry. The principal vegetation consists of young tamaracks, cotton grass, cranberry, cassandra, andromeda and sphagnum. The peat is of a wet, brown and fibrous character, containing wood and seeds of plants and extends down 9 feet to sand.

PEAT SAMPLE SACK 330

	Air Dried	As Received	Dry Fuel	Combustible
Moisture, per cent	5.71	15.42	....	....
Volatile Matter, per cent	59.19	53.09	62.77	69.37
Fixed Carbon, per cent	26.13	23.44	27.71	30.63
Ash, per cent	8.97	8.05	9.52	....
B. T. U., per pound	8,856	7,943	9,391	10,379
Sulphur, per cent	.21	.19	.22	.24

Air drying loss: 10.30 per cent.

PEAT SAMPLE BOTTLE 330

	Air Dried	As Received
Moisture, per cent	5.74	87.18

Air drying loss: 86.40 per cent.

Eagle River Bog

A 500-acre cassandra bog, crossed by the C. & N. W. Ry., lies 2 miles south of Eagle river. The vegetation found here consists of cassandra, andromeda, sphagnum, cranberry, cotton grass, tamarack, labrador tea, sedge and grass.

At the point examined, the deposit was 9 feet deep and rested upon a bed of blue clay.

PEAT SAMPLE SACK 331

	Air Dried	As Received	Dry Fuel
Moisture, per cent	5.21	15.83	....
Volatile Matter, per cent	60.14	53.40	63.44
Fixed Carbon, per cent	24.06	21.37	25.39
Ash, per cent	10.59	9.40	11.17
B. T. U., per pound	8,869	7,875	9,356
Sulphur, per cent	.26	.23	.27

Air drying loss: 11.20 per cent.

PEAT SAMPLE BOTTLE 331

	Air Dried	As Received
Moisture, per cent	5.13	86.43

Air drying loss: 85.70 per cent.

ANTIGO MARSHES

The marshy areas in the immediate vicinity are scarce. About 3 miles southwest of the city is a marshy tract covering perhaps 50 acres. The peat deposit is but $1\frac{1}{2}$ feet deep and is underlaid by sand. Ferns, moss and smartweed are the principal small plants, while cedar, tamarack and balsam make up the larger vegetation.

PEAT SAMPLE BOTTLE 332

	Air Dried	As Received	Dry Fuel
Moisture, per cent	7.67	80.24	....
Volatile Matter, per cent	43.04	9.21	46.61
Fixed Carbon, per cent	19.47	4.17	21.10
Ash, per cent	29.82	6.38	32.29
B. T. U., per pound	5,870	1,256	6,358
Sulphur, per cent	.60	.13	.66

Air drying loss: 78.60 per cent.

Mountain Marshes

Mountain is a small lumbering town on the C. & N. W. Ry., lying in a country that is rather new and wild. There are many small marshy tracts, being principally swamps covered with cedar, spruce and tamarack.

A 60-acre tract of this kind was sampled and a very wet, black, decomposed peat was found to a depth of 3½ feet. Below the peat deposit was sand.

PEAT SAMPLE SACK 333

	Air Dried	As Received	Dry Fuel	Combustible
Moisture, per cent	7.95	19.82	....	....
Volatile Matter, per cent	54.46	47.43	59.15	68.12
Fixed Carbon, per cent	25.47	22.19	27.68	31.88
Ash, per cent	12.12	10.56	13.17	....
B. T. U., per pound	7,191	6,264	7,812	8,996
Sulphur, per cent	.69	.60	.75	.86

Air drying loss: 12.90 per cent.

PEAT SAMPLE BOTTLE 333

	Air Dried	As Received
Moisture, per cent	7.24	87.57

Air drying loss: 86.60 per cent.

PEAT MARSH AT MADISON, DANE COUNTY

University Bay marsh, showing (1) Sedge and grass in foreground. (2) Cat-tails at sides of picture, (3) Arrow leaf in center, (4) Rising land in background indicating horder of marsh This picture represents a type of peat marsh very common in the southern part of the state.

SPHAGNUM BOG AT HEAFFORD JUNCTION, ONEIDA COUNTY

This bog resembles a great sponge. The sphagnum moss absorbs the water contained in the bog. A person, walking over the surface, sinks in up to his knees. Cassandra, Andromeda, Labrador Tea and Cotton grass are prominent on deposits of this kind.

CHAPTER VII
SUMMARY OF THE CHARACTERISTICS OF WISCONSIN PEAT

Occurrence

The largest and best peat deposits are located in the eastern half of the state. A fewer number of deposits, both smaller in area and poorer in quality, are found in the western half of the state. Perhaps the largest and more important deposits are located in the southeastern quarter of the state, and the deposits second in importance are found in the northeastern quarter. The northwestern quarter of the state has still fewer good peat marshes, while the southwestern quarter has practically none.

The value of the northern and western deposits of peat are lowered because they lie in a country as yet sparsely populated and largely undeveloped, hence there is practically no good market for peat close at hand. Further, the gradual removal of timber and the consequent erosion of land in these sections cause more or less sand and clay to be washed into the lowlands, thus contaminating the peat and making its ash content high.

Types of Peat

Wisconsin peat may be grouped broadly into three more or less distinct types, viz:

(1) Moss-like, partially decomposed peat, usually light colored
(2) Clay-like, muddy, thoroughly decomposed peat, usually dark brown or black in color, and
(3) Algal, or gray, soft, plastic, decomposed peat.

The moss-like peat, as its name implies, is made up principally of the remains of mosses. It usually has a coarse, porous, spongy texture and has a gray or light brown color. The remains of plants from which it was formed are usually distinguishable in it and, on the whole, the peat is but slightly decomposed. It occurs characteristically in areas known as built-up or moist depression fillings. Sphagnum moss is the most common plant found upon deposits of

this kind and, in addition, there will usually be found some sedges, shrubs like cassandra and andromeda, and cone-bearing plants. In deposits where sphagnum and the heaths predominate, the peat is usually very poorly decomposed, spongy and light-brown colored. Other deposits, upon which conifer growths predominate, contain peat which is likely to be darker and more thoroughly decomposed but still fibrous, coarse and brown.

The dark-brown or black, thoroughly decomposed type of peat is usually found to be of a muddy, sticky and clay-like consistency. It is compact and thoroughly decomposed and is most useful for commercial utilization as a fuel. Peat found underlying meadow marshes is usually of this variety. This type of peat is formed principally by aquatic seed plants such as pond lilies, bulrushes, sedges, grasses, etc., and accumulates in bodies of standing water, often called "filled basins" or "lake fillings."

While the two types of peat just described are most common and are sometimes supposed to be the only existing types, there is another product of plant decay which may be described as algal peat. Indeed, there is some controversy as to whether or not this product may rightly be called peat at all. At the bottom of some of the bogs there will be found in the process of formation beds of soft, gray or light-colored, fine-grained, structureless peat of a cheesy consistency, which upon examination under a microscope is found to be composed largely of the remains of algal or cellular plants, in which root, stem and leaves are not distinguishable. The growths known, as "pond-scums" belong to the algal plants which form this type of peat. Such algal peat was observed at the bottom of the deposits at Waupaca, Minocqua, Glidden and Sturgeon Bay. The origin and nature of this type of peat is still somewhat obscure but it is usually found at the bottom of a deposit and below layers of brown or black and more thoroughly decomposed peat.

Structure

In the preceding sections the peat and peat deposits of Wisconsin were divided into types whose principal characteristics were there discussed. But it must not be concluded that any such exact classifications will hold in all cases. On the contrary, considerable departure from these arbitrary groups will be observed.

As far as the different kinds of deposits are concerned, it will be found that two or more of them may and often do occur together. Similarly, if the structure and composition of the peat are considered,

they will be found to vary considerably in different bogs or even in different parts of any one bog. Chapters V and VI contain many examples of these facts. But to show a more detailed illustration of this variation in color and texture, a section of the bog at Heafford Junction is given below.

Section of Deposit at Heafford Junction

Surface—1 ft., vegetation, roots, sphagnum moss
1 ft.—6 ft., brown-fibrous material, containing sphagnum remains; seeds, roots, leaves partly decomposed
6 ft.—14 ft., similar material, very wet
14 ft.—16 ft., dark-brown, fibrous material, containing roots, stalks, etc.
16 ft.—18 ft., black thoroughly decomposed peat.
18 ft.—20 ft., sandy peat
20 ft.—bottom, sand

Further, the Glidden deposit may be cited as an example of the co-existence of different types of peat. Here the brown, fibrous peat and the algal peat are found in the same deposit, though at different depths. Frequently, also, the brown, fibrous and the black, decomposed peats will be found together in a similar manner.

Section of Deposit at Glidden

Surface—1½ ft., roots of growing sphagnum moss plants, with much water
1½ ft.—6 ft., brown, fibrous moss peat, containing roots and stalks of decayed plants
6 ft.—12 ft., same, much water
12 ft.—13 ft., denser layer of brown peat, with plant remains, containing seeds
13 ft.—14 ft., gray, algal peat, decomposed, slippery, of cheesy consistency
14 ft.—gray sand bottom

Briquetting Properties

That Wisconsin peat can be manufactured into briquet form has been demonstrated to be a fact. The author has seen excellent briquets that were made at Whitewater and Tomah. These resembled coal in appearance, were solid, compact, not at all brittle,

clean and easily handled. They were made in two sizes, approximately disk shaped, one size having the dimensions of 2 inches diameter and $\frac{3}{8}$ inch thickness, the other size being slightly larger.

Proximate Analysis

For common purposes, the proximate analysis, giving the contents of moisture, volatile matter, fixed carbon, ash, heating value and combustible, are the most important determinations, and they are generally sufficient to indicate the quality of peat.

In Chapters V and VI detailed tests were given covering the proximate analyses of Wisconsin peat. These have been collected and arranged in the following two tables. (See Tables 13 and 14). Further, for comparative purposes, etc., these tabulated data have been reduced to graphical form in the accompanying chart. (See Fig. 8). In the preparation of this chart the results for the dry or moisture free fuel were used.

A general discussion of these tables and the chart follows. The meaning of the several items is given in Chapter IV.

TABLE 13

TABLE SHOWING PROXIMATE ANALYSIS, HEATING VALUE, ETC., OF WISCONSIN PEAT. SURVEY OF 1903.

Location of Deposit	Deposit No.	Sample No.	As Rec'd	Dry Fuel				Combustible		
			Moisture %	Volatile Matter %	Fixed Carbon %	Ash %	B. T. U. Per Lb.	Volatile Matter %	Fixed Carbon %	B. T. U. Per Lb.
Stoughton	1	1	69.7	63.3	25.3	11.4	9,320	71.5	28.5	10,500
Stoughton	1	2	65.2	63.1	24.6	12.4	8,960	72.0	28.0	10,260
Stoughton	1	3	87.0	62.4	26.5	11.1	8,929	70.4	29.8	10,000
Stoughton	1	4	74.4	59.3	20.5	20.2	6,190	74.4	25.7	7,760
Stoughton	1	5	85.3	63.3	23.6	13.1	8,570	73.9	26.1	9,880
Whitewater	2	1	69.4	38.4	16.9	44.7	6,040	69.5	30.6	10,900
Whitewater	2	2	85.5	60.4	27.8	11.8	9,440	68.5	31.6	10,700
Whitewater	2	3	82.8	58.2	26.6	15.2	9,040	68.7	31.4	10,650
Whitewater	2	4	*33.4	57.4	25.4	17.2	9,370	69.4	30.7	11,300
Whitewater	2	5	*14.0	59.7	29.4	10.9	8,600	67.0	33.0	9,695
Whitewater	3	1	83.0	52.2	28.3	19.5	8,060	64.9	35.2	10,000
Whitewater	3	2	82.9	62.0	28.7	9.3	8,370	68.4	31.6	9,250
Whitewater	3	3	80.7	57.2	27.0	15.8	8,600	68.0	32.0	10,200
Whitewater	4	1	81.1	55.7	25.1	19.2	7,920	69.0	31.1	9,800
Whitewater	4	2	80.7	53.1	32.3	14.6	8,400	62.3	37.8	9,900
Lake Beulah	5	1	*58.5	58.5	28.6	12.9	8,280	67.3	32.8	9,600
Lake Beulah	5	2	*14.0	56.7	30.9	12.4	8,870	64.7	35.2	10.100
Lake Beulah	5	3	83.5	59.3	27.5	13.2	8,870	68.1	31.9	10,200
Dousman	6	1	...	...	...	...	...	...	...	...
Madison	7	1	...	...	...	...	...	...	...	...
Glenbeulah	8	1	88.2	64.5	29.0	6.5	9,060	69.0	31.0	9,700
Glenbeulah	8	2	89.4	68.7	25.7	5.6	10,600	72.9	27.1	11.200
Glenbeulah	8	3	90.5	67.2	25.3	7.6	9,500	72.7	27.3	10,300
Glenbeulah	8	4	90.6	63.8	24.8	11.4	8,500	72.1	27.9	9,600
Glenbeulah	8	5	89.4	65.3	23.6	11.1	8,650	73.5	26.5	9,700
Medina	9	1	83.8	63.8	28.6	7.6	8,700	69.0		9,450
Medina	9	2	69.1	43.4	14.2	42.4	3,700	75.3	24.7	6,300
Medina	9	3	88.8	59.8	29.4	10.8	8,400	67.1	32.9	9,500
Medina	9	4	83.4	61.7	30.0	8.3	9,800	67.2	32.8	10,600
Medina	9	5	83.5	56.2	29.7	14.1	8,600	65.5	34.5	9,900
Medina	9	6	80.0	62.6	19.3	18.1	7,300	76.5	23.5	8,900
Fond du Lac	10	1	83.1	61.8	26.8	11.4	8,800	69.9	30.1	9,900
Fond du Lac	10	2	81.4	60.6	24.0	15.4	8,800	71.7	28.3	10,400
Fond du Lac	10	3	79.5	43.7	29.8	26.5	4,800	59.5	40.5	6,600
Fond du Lac	10	4	80.1	55.4	27.5	17.1	6,900	66.9	33.1	8,300
Fond du Lac	10	5	84.0	61.1	29.0	9.9	8,700	68.0	32.0	9,600
Fond du Lac	10	6	88.9	70.5	21.8	7.7	10,300	76.5	23.5	11,100
Chester	11	1	79.0	55.3	28.4	16.3	7,300	66.2	33.8	8,770
Chester	11	2	77.7	48.0	23.3	28.7	7,600	66.4	33.6	10,600
Chester	11	3	78.6	52.7	25.4	21.9	7,100	67.5	32.6	9,100
Chester	11	4	77.9	47.9	23.8	28.3	6,700	66.9	33.1	9,400
Chester	11	5	82.0	58.1	17.8	24.1	6,870	76.6	23.4	9,000
Mendota	12	1	86.4	64.1	25.1	10.8	8,700	72.8	27.2	9,800
Mendota	12	2	86.6	60.1	25.5	14.4	8,400	70.4	29.6	9,600
Mendota	12	3	86.5	57.7	26.4	15.9	8,100	68.6	31.4	9,600
Mendota	12	4	85.8	56.9	25.9	17.2	7,800	68.7	31.3	9,500
Mendota	12	5	85.4	54.0	31.8	14.2	7,800	63.0	37.0	9,200
Mendota	12	6	68.6	63.1	27.6	9.3	9,200	69.6	30.4	10,100
Markesan	13	1	85.1	60.8	30.1	9.1	9,500	67.1	32.9	10,400
Markesan	13	2	67.0	45.9	7.1	47.0		...	...	...
Marshall	14	1	*18.6	60.9	27.9	11.2	9,000	68.8	31.4	10,200
Rhinelander	15	1	89.3	66.2	28.3	5.5	10,600	70.1	29.9	11,300
Rhinelander	15	2	91.4	66.3	27.3	6.4	9,600	70.9	29.1	10,300
Rhinelander	15	3	89.4	71.3	22.8	5.9	9,200	75.8	24.2	9,800
Rhinelander	15	4	90.7	66.0	28.5	5.5	9,960	69.9	30.1	10,500
Rhinelander	16	1	...	...	...	...	...	...	...	...
Rhinelander	17	1	...	...	...	...	...	...	...	...

* Star indicates 5 samples which were partially air-dried before analysis and do not, therefore, indicate the moisture content of samples as taken from the bog.

TABLE 14

Table Showing Proximate Analysis, Heating Value, etc., of Wisconsin Peat. Survey of 1908.

			Air Dried						As Received						Dry Fuel				
Location of Deposit	Deposit No.	Air Drying Loss %	Moist-ure %	Volatile Matter %	Fixed Carbon %	Ash %	B. T. U. Per Lb.	Sulphur %	Moist-ure %	Volatile Matter %	Fixed Carbon %	Ash %	B. T. U. Per Lb.	Sulphur %	Volatile Matter %	Fixed Carbon %	Ash %	B. T. U. Per Lb.	Sulphur %
Madison	301	61.50	9.26	47.18	17.89	25.67	6,250	.42	65.07	18.16	6.89	9.88	2,407	.16	51.99	19.73	28.28	6,890	.45
Madison	301	82.00	8.60						†83.55										
Madison	302	68.50	8.99	50.82	21.42	18.77	6,943	.38	71.33	16.01	6.75	5.91	2,187	.12	55.84	23.55	20.61	7,628	.42
Madison	302	84.30	6.92						†85.33										
Fond du Lac	303 B	73.80	11.99	51.03	21.75	15.23	7,169	.66	76.91	13.37	5.70	3.99	1,879	.17	57.98	24.72	17.30	8,149	.74
Fond du Lac	303 B	85.00	7.72						†86.16										
Fond du Lac	303 A	6.60	9.95	48.14	25.14	16.77	7,468	.79	15.89	44.96	23.49	15.66	6,975	.74	53.45	27.93	18.62	8,293	.88
Waupaca	304	19.40	6.95	54.23	23.44	15.38	7,614	.37	25.00	43.71	18.89	12.40	6,136	.30	58.29	25.18	16.53	8,181	.40
Waupaca	304	85.60	6.90						†86.59										
Waupaca	305	13.00	6.62	55.31	13.63	24.44	6,970		18.76	48.12	11.86	21.26	6,064		59.23	14.60	26.17	7,465	
Waupaca	305	94.90	7.64						†95.29										
Kiel	306	16.40	7.70	48.38	16.00	27.92	6,107	1.51	22.84	40.45	13.37	23.34	5,107	1.26	52.42	17.33	30.25	6,619	1.63
Kiel	306	83.60	7.74						†84.82										
Kiel	307	28.40	6.82	52.30	21.42	19.46	7,256	1.51	33.28	37.45	15.34	13.39	5,195	1.08	56.13	22.99	20.88	7,787	1.62
Kiel	308	20.40	7.79	53.04	20.85	18.32	7,119	.82	26.60	42.22	16.60	14.58	5,666	.65	57.52	22.62	19.86	7,720	.89
Kiel	308	86.90	9.25						†88.11										
Kiel	309		8.22	58.07	23.21	10.50	8,032	.64	20.43	50.35	20.12	9.10	6,964	.55	63.28	25.28	11.44	8,753	.69
Kiel	309	90.30	7.79						†91.06										
Bloomer	310	72.90	11.76	41.80	15.30	31.14	5,503	.28	76.09	11.33	4.14	8.44	1,490	.08	47.39	17.31	35.30	6,233	.33
Bloomer	310	80.10	9.15						†81.92										
Bloomer	311	75.80	10.35	49.26	24.74	15.65	7,929	.21	78.30	11.92	5.99	3.79	1,919	.05	54.93	27.60	17.47	8,842	.23
Bloomer	311	82.20	7.67						†83.57										
Ashland	312	45.30	6.82	26.69	6.38	60.11	2,984	.24	49.03	14.60	3.49	32.88	1,633	.13	28.64	6.85	64.51	3,202	.26
Ashland	312	61.30	4.57	22.60	5.64	67.19		.18	†63.07	8.75	2.18	26.00		.07	23.69	5.91	70.40		.19
Hayward	313	9.00	10.21	50.77	25.06	13.96	7,866	.26	18.29	46.20	22.81	12.70	7,159	.24	56.54	27.92	15.54	8,761	.29
Hayward	313	90.80	6.66						†91.41										
Hayward	314	11.30	7.71	51.13	20.07	21.09	7,411	.39	18.14	45.35	17.80	18.71	6,574	.35	55.40	21.74	22.86	8,028	.43
Hayward	314	91.10	3.93						†91.45										
New Auburn	315	4.90	7.66	53.55	25.48	13.31	8,222	.20	12.18	50.93	24.23	12.66	7,819	.19	57.99	27.59	14.42	8,906	.22
New Auburn	315	92.50	4.95						†92.87										
Cameron	316	9.30	5.21	60.08	26.78	7.93	8,716	.28	14.03	54.49	24.29	7.19	7,906	.25	63.38	28.26	8.36	9,196	.29
Cameron	316	90.50	7.22						†91.19										

Ladysmith	317	7.80	3.85	54.00	20.98	21.17	7,646	.21	11.35	49.79	19.34	19.52	7,051	.22	56.16	21.82	22.02	7,952	.25
Ladysmith	317	88.50	5.31						†89.11										
Heafford Jct.	318	10.10	4.07	53.63	20.44	21.86	7,722	.23	13.76	48.21	18.38	19.65	6,943	.21	55.90	21.31	22.79	8,051	.24
Heafford Jct.	318	93.70	5.08						†94.02										
Minocqua	319	15.10	5.72	50.08	20.82	23.38	7,456	.28	19.96	42.52	17.67	19.85	6,331	.24	53.12	22.08	24.80	7,909	.30
Minocqua	319	83.20	4.12						†83.89										
Minocqua	320	9.20	4.58	51.92	18.82	24.68	7,236	.50	13.36	47.14	17.09	22.41	6,570	.45	54.41	19.72	25.87	7,583	.52
Minocqua	320	92.50	4.36						†92.83										
Lac du Flambeau	321	10.80	2.68	53.52	22.84	20.96	8,417	.16	13.19	47.47	20.37	18.70	7,508	.14	51.99	23.47	21.51	6,649	.16
Lac du Flambeau	321	83.70	5.02						†84.52										
Powell	322	11.40	6.56	53.04	25.32	15.08	7,627	.89	17.21	46.99	22.44	13.36	6,757	.79	56.76	27.10	16.14	8,161	.95
Powell	322	87.50	6.29						†88.29										
Glidden	323	9.00	4.62	58.33	25.76	11.29	8,723	.22	13.20	58.08	23.45	10.27	7,938	.20	61.15	27.02	11.83	9,146	.23
Glidden	323	91.80	6.33						†92.32										
Park Falls	324	8.00	3.99	42.81	18.95	34.25	6,291	.30	11.67	39.39	17.43	31.51	5,787	.28	44.59	19.74	35.67	6,552	.32
Park Falls	324	71.10	5.63						†72.73										
Kewaunee	325	6.10	8.96	53.94	23.60	13.50	7,290	.47	14.51	50.65	22.16	12.68	6,845	.44	59.25	25.92	14.83	8,006	.51
Kewaunee	325	86.70	7.88						†87.85										
Algoma	326	3.50	7.51	38.52	15.19	38.78	5,445	.26	10.75	37.17	14.66	37.42	5,254	.25	41.65	16.42	11.93	5,886	.28
Algoma	326	67.60	7.63						†70.07										
Sturgeon Bay	327	6.30	9.01	54.73	16.20	20.06	7,185	.77	14.74	51.28	15.18	18.80	6,731	.72	60.15	17.80	22.05	7,898	.84
Sturgeon Bay	327	91.40	8.77						†92.15										
Peshtigo	328	75.10	5.05	43.29	18.69	32.95	6,012	.66	76.36	10.78	4.66	8.20	1,498	.16	45.60	19.71	31.69	6,334	.68
Pembine	329	6.60	9.25	50.60	23.15	17.00	7,112	1.51	15.42	47.16	21.58	15.84	6,628	1.41	55.75	25.52	18.73	7,835	1.67
Pembine	329	82.80	6.80						†83.97										
Gagen	330	10.30	6.71	59.19	26.13	8.97	8,856	.21	15.42	53.09	23.44	8.05	7,943	.19	62.77	27.71	9.52	9,391	.22
Gagen	330	86.40	5.74						†87.18										
Eagle River	331	11.20	6.21	60.14	24.06	10.59	8,869	.26	15.83	53.40	21.37	9.40	7,875	.23	63.44	25.39	11.17	9,356	.27
Eagle River	331	85.70	5.13						†86.43										
Antigo	332	78.60	7.67	43.04	19.47	29.82	5,870	.60	80.24	9.21	4.17	6.38	1,256	.13	46.61	21.10	32.29	6,358	.66
Mountain	333	12.90	7.95	54.46	25.47	12.12	7,191	.69	19.82	47.43	22.19	10.56	6,264	.60	59.15	27.68	13.17	7,812	.75
Mountain	333	86.60	7.24						†87.57										

† Indicates samples of raw peat with moisture content as collected directly from marsh.

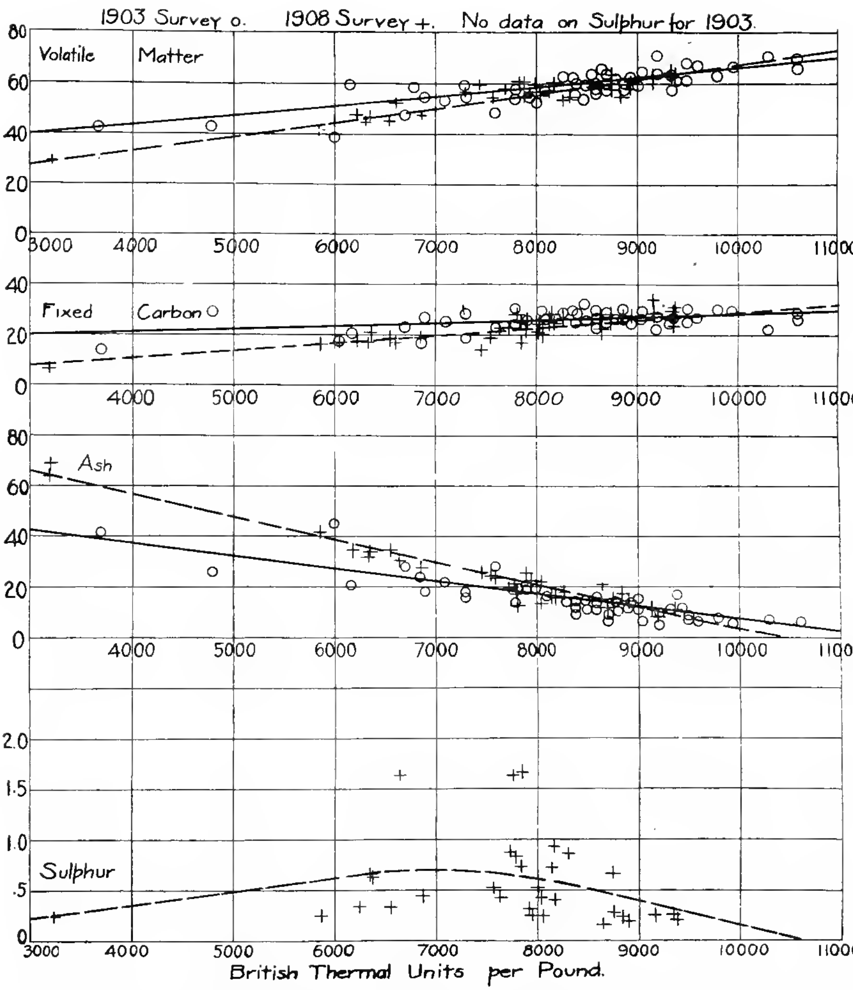


FIG. 8. RELATION BETWEEN HEATING VALUE, VOLATILE MATTER, FIXED CARBON AND ASH FOR WISCONSIN PEAT

Moisture

Peat is totally unfit for use as a fuel until it has been dried. The economical removal of the large amount of water which peat contains is of great importance in the art of peat utilization and constitutes the main problem and principal stumbling block in the development of the peat industry.

As dug from the marsh, raw peat contains water in amounts ranging from 65 to 90 or more per cent by weight. That is, the percentage of peat substance ranges from less than 10 to about 35 per cent of the total weight. When drained and settled, a bog contains peat still having from 85 to 90 per cent of water. Air-dried peat has about 25 per cent moisture, or 75 per cent peat substance and, under specially favorable conditions, it sometimes has as little as 15 per cent moisture.

In these respects, Wisconsin peat does not differ materially from other peats. We may consider the moisture content of Wisconsin peat from various points of view as follows:

Moisture in Raw Peat

To interpret the data of the tables, the following explanation is needed. The samples collected in the 1903 survey were enclosed in air-tight bottles as soon as collected in the field and were then shipped to the laboratory in this condition. These samples were then analysed in the laboratory and the results are given in Table 13 in the column headed "As Received, Moisture." This column, therefore, shows the moisture contained in the raw peat as collected from the bog. Five of the samples, however, which are indicated in Table 13 thus (*), were not raw peat samples, but were partially or wholly air-dried before analysis. Consequently, these five samples cannot be considered in determining the amount of moisture in the raw peat as found in the bog. Neglecting these five, and considering the remaining 48 specimens, we find the results for 1903 shown in Table 15, column 2.

A similar plan was followed in the 1908 survey. Partially air-dried samples and raw samples are included in Table 14. But the samples of raw peat then collected are indicated thus, (†) in Table 14. Considering these 30 samples, we find results for 1908 as shown in Table 15, column 3.

A general average of the two surveys is also given, Table 15, column 4.

Here it will be seen that the percentage of moisture in the raw peat of Wisconsin, as collected from the bog, ranges from approximately 64 to 93 per cent and that the general average is about 84.5 per cent.

TABLE 15

TABLE SHOWING MOISTURE IN RAW PEAT

	1903*	1908†	Average 1903–1908
	Per cent	Per cent	Per cent
Maximum	91.4	95.29	93.3
Minimum	65.2	63.07	64.1
Average	82.7	86.31	84.5

*Considering 48 samples of 1903 survey, except those marked * in Table 13, for reasons explained.

†Considering 30 samples of 1908 survey, marked † in Table 14 for reasons explained.

Moisture in Air-dried Peat

Raw peat, taken indoors and exposed to room conditions, can be quite thoroughly dried. Handled in this manner, the moisture content of the Wisconsin samples of 1908 was found to range from 2.5 to 12 per cent. (See Table 14, column headed "Air Dried Moisture.") But in speaking of "air-dried peat," we rarely mean peat dried in this way. By that term we mean, rather, peat, which, after having been dug, is exposed to out-of-door conditions, either unprotected from the elements or protected from them by sheds or otherwise. And where the term "air-dried" is used in the present section, the latter meaning is intended.

Several air-dried samples of Wisconsin peat were obtained and analysed. The moisture content of same, together with a brief explanation of the conditions to which they were exposed, etc., are given in Table 16.

The maximum moisture content was 58.5 per cent; the minimum, 14.0 per cent; the average, 26.9 per cent. It is seen that the moisture content of air-dried peat depends in a large measure upon the conditions of weather to which it is exposed.

TABLE 16

TABLE SHOWING MOISTURE CONTENT IN AIR-DRIED WISCONSIN PEAT

Location	Deposit	Sample	Air Dried Moisture %	Remarks
Whitewater.............	2	4	33.4	Sample was taken from some of the unground and artificially dried, not compressed product at Whitewater factory. It had been standing for some months.
Whitewater.............	2	5	14.0	Sample was taken from some of the compressed commercial products made in 1902 at the Whitewater factory. Said to have been stored in a rather damp place.
Lake Beulah............	5	1	58.5	Sample taken from some air-dried, pulverized peat, taken out by P. J. Buckley, for experimental purposes. Had been piled in open air for five or six months. Was covered with snow when sample was taken.
Lake Beulah............	5	2	14.9	Sample taken from some pulverized, dried peat, prepared by P. J. Buckley for experimental purposes. Dried artificially in open air and stored in sheds in marsh.
Marshall..................	14	1	18.6	This sample was collected by Prof. Baldwin of Marshall. It was taken from the surface and sent in to be tested. It was evidently partially air-dried en route.
Fond-du-Lac..........	303A	....	15.89	Some of the machined and unfinished peat, taken from the storage bins in the abandoned peat factory. Bins covered, but open to the outdoor air. Had lain several years.
Kiel..........................	307	....	33.28	Sample dug from deposit by Reinhardt Thiessen, of Kiel, and had lain on the ground in the swamp for about one year.

Average of above 7 samples............... 26.9

Volatile Matter

Data upon volatile matter, fixed carbon, ash and heating value will be given for the dry and moisture-free condition of the peat. This is done for the reason that Tables 13 and 14 both contain results reduced to these terms and, for the further reason, that fuels can be compared upon this basis more readily.

Table No. 17 gives the minimum, maximum and average percentages of volatile matter in Wisconsin peat. It will be observed that the volatile constituents comprise 56.4 per cent of the peat in its dry or moisture-free condition.

TABLE 17

Volatile Matter in Wisconsin Peat—For Dry or Moisture-Free Fuel

	1903	1908	Average 1903–1908
	Per cent	Per cent	Per cent
Minimum	38.4	23.69	
Maximum	71.3	63.44	
Average	59.0	53.8	56.4

These volatile matters make up that portion of the fuel which is driven off by the application of heat. They consist principally of hydrocarbons or complex compounds of hydrogen and carbon chemically combined in various proportions, such as benzine (C_6H_6), ethylene (C_2H_4), acetylene (C_2H_2), methane or marsh gas (CH_4), etc. Other gases, like oxygen (O) and nitrogen (N), in small quantities, are also a portion of the volatile matter. The volatile matters are the chief gaseous products resulting from the distillation of peat in retorts.

Fixed Carbon

That portion of the carbon in a fuel, which is not volatile, is called "fixed carbon." It is that carbon remaining in the fuel after the volatile matters have been driven off. The amount of fixed carbon is important since, in a measure, it indicates the value of the coke formed from peat after distillation. (See Table 18.)

TABLE 18

FIXED CARBON IN WISCONSIN PEAT—FOR DRY AND MOISTURE-FREE FUEL

	1903	1908	Average 1903–1908
	Per cent	Per cent	Per cent
Minimum	7.1	5.91	....
Maximum	32.3	27.93	....
Average	25.8	22.2	24.0

COMBUSTIBLE CONTENTS

Volatile matters and fixed carbon constitute the combustible materials in a fuel. The average amounts of these found in the preceding paragraphs are 56.4 per cent for the volatile matter and 24.0 per cent for the fixed carbon, and the sum of these, 80.4 per cent, is the combustible in the dry fuel.

ASH

Ash content is determined by subtracting the sum of the combustible materials from the total weight of dry peat. The total combustible was found to be 80.4 per cent, therefore, the difference between 100.0 per cent and 80.4 per cent gives the ash contents amounting to 19.6 per cent.

An average of the ash percentages given in Tables 13 and 14 shows a value of 19.2 per cent. This affords a reasonably close check.

The following table is also appended.

TABLE 19

ASH IN WISCONSIN PEAT—FOR DRY AND MOISTURE-FREE FUEL

	1903	1908	Average 1903–1908
	Per cent	Per cent	Per cent
Minimum	5.5	8.36	....
Maximum	47.0	70.40	....
Average	14.6	23.9	19.2

Sulphur

Sulphur determinations were made for the 1908 samples only. The percentages as found are; minimum 0.16 per cent, maximum 1.67 per cent, and average 0.55 per cent.

Heating Value

The value of a fuel depends largely upon the amount of heat which it will generate upon combustion. Heating value is measured and expressed in thermal units per pound of fuel. The thermal unit most commonly used is the British Thermal Unit or B. T. U., and this is the amount of heat that will raise the temperature of one pound of water 1 degree Fahrenheit.

The average heating value of the Wisconsin samples is found to be 8,070 B. T. U., per pound of dry fuel. See Table 20 for other data on heating value.

TABLE 20

Heating Value of Wisconsin Peat—For Dry and Moisture-Free Fuel

	1903	1908	Average 1903–1908
	B. T. U.	B. T. U.	B. T. U.
Minimum	3,700	3,202	
Maximum	10,600	9,391	
Average	8,390	7,750	8,070

Summary of Data on Proximate Analysis

The several minimums, maximums and averages of the items making up the proximate analysis of Wisconsin peat may be summarized as in Table 21.

TABLE 21

MINIMUM, MAXIMUM AND AVERAGE DATA FOR PROXIMATE ANALYSIS OF WISCONSIN PEAT

For Dry and Moisture-free Fuel

		1903	1908	Average 1903-1908
Volatile Matter, per cent	Minimum	38.4	23.69	
	Maximum	71.3	63.44	
	Average	59.0	53.8	56.4
Fixed Carbon, per cent	Minimum	7.1	5.91	
	Maximum	32.3	27.93	
	Average	25.8	22.2	24.0
Ash, per cent	Minimum	5.5	8.36	
	Maximum	47.0	70.40	
	Average	14.5	23.9	19.2
Sulphur, per cent	Minimum		0.16	
	Maximum		1.67	
	Average		0.55	0.55
B. T. U., per pound	Minimum	3,700	3,202	
	Maximum	10,600	9,391	
	Average	8,390	7,750	8,070

RELATIONS BETWEEN HEATING VALUE, VOLATILE MATTER, FIXED CARBON, ASH AND SULPHUR

The curves in Figure 8 bring out the relations existing between the heating value and the volatile matter, fixed carbon, ash and sulphur for the dry and moisture-free Wisconsin peat. It is seen that the volatile matter and fixed carbon increase and the ash decreases as the heating value increases. In other words, those peats having the highest heating values are also the ones having the greatest percentages of volatile matter and fixed carbon and the smallest percentages of ash. Apparently sulphur content does not follow any particular law.

The greatest number of B. T. U. values seem to lie between 6,000 and 9,600 B. T. U. and the ash content of the samples lying between these limits varies from 40 to 8 per cent. That is, in a range of 3,600 B. T. U., there is a range of 32 per cent. Hence, the decrease in thermal value is at the rate of 112 B. T. U. for every 1 per cent increase in ash content.

ULTIMATE ANALYSIS

Just a few ultimate analyses of Wisconsin peat were made and these were upon samples of the 1908 survey. Results are given in Table 22. These are perhaps sufficient to indicate the general chemical composition of the peat and serve for making comparisons with other fuels.

TABLE 22

TABLE SHOWING ULTIMATE ANALYSIS OF WISCONSIN PEAT
Survey of 1908

Location of Deposit	Deposit No.	B. T. U. per Lb.	C %	H %	O %	N %	S %	Ash %
		As Received						
Fond du Lac	303 B	1,730	10.87	9.57	74.72	.68	.17	3.99
Waupaca	305	5,686	42.71	6.09	27.07	2.30	.57	21.26
Hayward	313	6,777	41.67	5.88	37.94	1.57	.24	12.70
Pembine	329	6,435	39.62	5.51	36.17	1.45	1.41	15.84
		Air-Dried						
Fond du Lac	303 B	....	11.50	5.22	34.81	2.58	.66	15.23
Waupaca	305	....	37.60	5.35	29.32	2.61	.65	24.44
Hayward	313	....	45.79	5.36	32.91	1.72	.26	13.96
Pembine	329	....	42.51	5.10	32.32	1.56	1.51	17.00
		Dry Fuel						
Fond du Lac	303 B	....	47.14	4.42	27.15	2.95	.74	17.30
Waupaca	305	....	40.26	4.94	25.10	2.83	.70	26.17
Hayward	313	....	51.00	4.71	26.54	1.92	.29	15.51
Pembine	329	....	46.84	4.49	26.56	1.71	1.67	18.73

An Average Sample of Wisconsin Peat

Based upon the results of the 1903 and 1908 surveys, the following data would represent approximately the characteristic quality of Wisconsin peat. Individual samples ranged between the maximum and minimum values shown in the following:

TABLE 23

Average, Maximum and Minimum Values of Proximate Analyses of Wisconsin Peat

		Range	
	Average	Maximum	Minimum
Moisture in raw peat, per cent	84.5	93.3	64.1
Moisture in air dried peat, per cent	26.9	58.5	14.0
Volatile Matter, per cent	56.4	71.3	23.7
Fixed Carbon, per cent	24.0	32.3	5.9
Ash, per cent	19.5	70.4	5.5
Sulphur, per cent	0.55	1.67	0.16
B. T. U., per pound	8.070	10,600	3,202
Combustible Contents, per cent	80.4	......	......
Carbon, per cent	46.3	51.0	40.3
Hydrogen, per cent	4.6	4.9	4.4
Oxygen, per cent	26.4	27.5	25.1
Nitrogen, per cent	2.35	2.9	1.7

Comparison of Wisconsin Peat with Foreign Peat

In order that the quality of Wisconsin peat may be compared with other peats, the tables given below are shown.

TABLE 24

Swedish Scale for Comparing Dry Peats*

Fuel Value

	Very High	High	Average	Low	Very Low
Calories per kilogram	5,600	5,300	5,000	4,700	4,400
British Thermal Units, per pound	10,080	9,540	9,000	8,460	7,920

Ash

	Low	Average	Comparat'y High	High	Very High
Per cent, approximate	2	5	8	11	14

*Torftjanstemannens verksamhet, 1905.

TABLE 25

CHEMICAL COMPOSITION OF DRY PEAT SUBSTANCE FROM BOGS IN DIFFERENT LOCALITIES

Peat From	100 Parts Dry Peat Contain					Moisture in the Air-Dried Peat
	Carbon	Hyd'g'en	Nitrogen,	Oxygen	Ash	
Cappoge, Ireland	51.05	6.85	39.55		2.55	10.0
Kulbeggen, Ireland	61.04	6.67	30.46		1.83	....
Philipstown, Ireland	58.69	6.97	1.45	32.88	1.99	....
Rammstein, Germany	62.15	6.29	1.66	27.20	2.70	16.7
Niedermoor, Germany	47.90	5.80	42.80		3.50	17.0
Bremen, Germany	57.84	5.85	0.95	32.76	2.60	....
Schopfloch, Germany	53.59	5.60	2.71	30.32	8.10	20.0
Grunewald, Germany	49.88	6.50	1.16	42.42	3.72	....
Haspelmoor, Germany	58.93	5.72	35.35		8.43	15.5
Kolbermoor, Germany	58.51	6.17	35.32		4.21	15.5
Holland	50.85	4.64	30.25		14.25	....
Sweden	54.13	6.45	39.42		1.89	....
Sweden	54.56	5.95	39.49		3.08	....
Sweden	53.34	5.70	40.96		1.78	....
Sweden	55.33	5.31	39.36		9.97	....
Sweden	57.14	5.95	36.91		7.10	....
Sweden	58.26	5.73	36.01		8.69	....

The average composition of 57 samples of Swedish peat fuel as given in Svenska mosskulturforeningens tidskrift, Jan. 1905, was found to be:

Moisture	27.17 %
Ash	3.27 %
Combustible substance	69.56 %

The calorific value of the original samples (with their contents of moisture) varied between 2,235—4,307 calories per kilogram, averaging 3,463 calories or 6,223 B. T. U. per pound.

The calorific value of the dried samples varied between 4,530—5,740, averaging 5,266 calories per kilogram or 9,478 B. T. U. per pound.

TABLE 26

PEAT FUEL FROM DENMARK*

Locality	Ash %	Sulphur %	Nitrogen %	Organic Subst'ce %	Moist're %	Caloric Value of sample with its Percentage of Moisture Calories
Bjornkaer	4.1	0.31	....	70.69	25.0	3,730
Lyngen	8.0	0.30	....	66.70	25.0	3,600
Korsor	10.8	1.80	1.2	62.40	25.0	3,280
Axelvold	4.4	0.63	1.5	68.50	25.0	3,574
Pindstrup	0.84	trace	0.72	74.10	25.0	3,330
Okaer	8.10	....	....	66.90	25.0	3,343
Sparkaer	5.00	....	....	70.00	25.0	3,644
Herning	1.40	....	....	73.40	25.0	3,582

*From Mosebladet, July 1907.

The average composition of Irish peat, disregarding sulphur, which is seldom present in appreciable quantities, may be taken as in Table 27.

TABLE 27

AVERAGE COMPOSITION OF IRISH PEAT†

Constituents	Perfectly Dry	Including 25% Moisture	Including 30% Moisture
Carbon	59.0	44.0	41.2
Hydrogen	6.0	4.5	4.2
Oxygen	30.0	22.5	21.0
Nitrogen	1.25	1.0	0.8
Ash	4.0	3.0	2.8
Moisture	....	25.0	30.0

†From "Mechanical Draft." Sturtevant, p. 42.

TABLE 28

COMPOSITION OF CANADIAN PEATS

Analyzed by Bureau of Mines, Toronto, and by the Geological Survey Department

Peat From	Moisture %	Ash %	Combustible Substance %
Welland	25.0	3.58	71.42
Perth	25.0	7.29	67.71
Brockville	25.0	8.20	66.80
Rondeau	25.0	7.03	67.97
Newington	25.0	0.92	74.08
Prince Edward Island	25.0	2.82	72.18
Ste. Therese	8.86	9.50	81.64

In 29 samples of Indiana peat the thermal values are distributed as follows:

TABLE 29

THERMAL VALUES OF INDIANA PEATS*

		British Thermal Units.
High	3 exceed	10,000
	6 lie between	9,500 and 10,000
	5 lie between	9,000 and 9,500
Medium	5 lie between	8,500 and 9,000
	5 lie between	8,000 and 8,500
Low	1 lies between	7,500 and 8,000
	1 lies between	7,000 and 7,500
	3 lie below	7,000

The ash percentages as determined in 5 samples range from 4.14 to 13.82 per cent.

*Thirty-first Annual Report, Dept. Geol. and Nat. Resources, Indiana, 1906, p. 111.

In 18 samples of peat from Michigan reported by C. A. Davis, the percentage of ash ranges from 1.3 to 18.8, and 19 determinations of thermal value were distributed as follows:

TABLE 30

THERMAL VALUES OF MICHIGAN PEATS*

		British Thermal Units.
High	5 exceed	10,000
	3 lie between	9,500 and 10,000
	1 lies between	9,000 and 9,500
Medium	3 lie between	8,500 and 9,000
	5 lie between	8,000 and 8,500
Low	1 lies between	7,500 and 8,000

*Davis, C. A., "Geological Survey of Michigan." Annual Report for 1906, p. 328.

MAINE PEAT

In a bulletin entitled "Peat Deposits of Maine" by E. S. Bastin and Charles A. Davis, are given a number of tests of Maine peats. The results are summarized in Figure 9. The authors bring

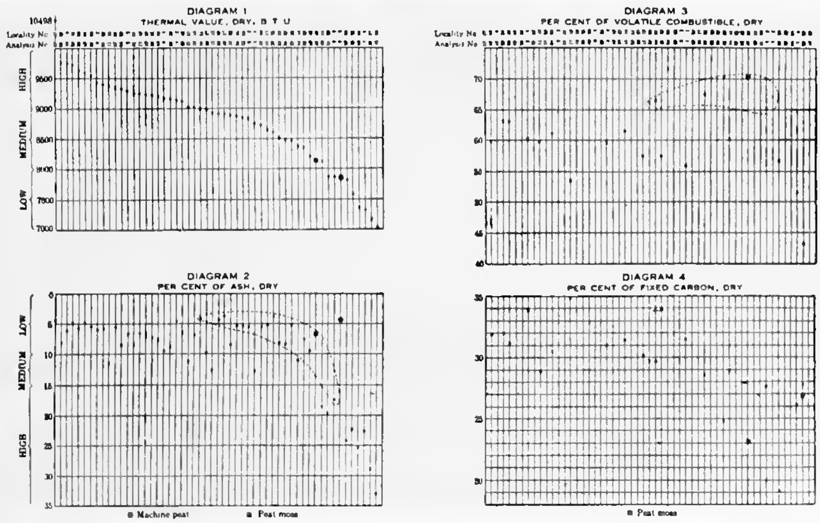


FIG. 9. THERMAL VALUE, ASH, VOLATILE COMBUSTIBLE AND FIXED CARBON IN MAINE PEAT

out the following points in their discussion of these diagrams. Most of the samples have a heating value lying between 8,100 and 9,800 B. T. U. Thirty out of 54 determinations lie between 8,500 and 9,500 B. T. U. Forty-five out of 54 samples showed less than 15 per cent

ash and 39 showed less than 10 per cent. Only 9 fell below 5 per cent. In most of the samples tested the percentage of volatile combustible lies between 50 and 70 and that of fixed carbon between 25 and 35.

Comparison of Wisconsin Peat with Other Fuels

In comparing the quality of Wisconsin peat with coal it will be sufficient to show analyses of some of the coals more commonly used in this state. Such comparisons have been made in Tables 31 and 32. For further comparisons with other fuels such as wood, oil, coke, gas, etc., see tables in Chapter I. Consult, also various books on fuels.

TABLE 31

Comparison of Wisconsin Peat With Various Coals Commonly Used in Wisconsin

Proximate Analysis

Locality	Class	Moisture	Volatile Matter	Fixed Carbon	Ash	Sulphur	B. T. U. per Lb. Fuel	B. T. U. Per Lb. Comb'l	Remarks
Pennsylvania	Anthra.	3.42	4.38	83.27	8.20	0.73	13,160	14,900	
Pocahontas, Va.	Semi-Bitu.	1.00	21.00	74.39	3.03	0.58	15,070	15,700	
Youghiogheny, Pa	Bitu.	1.03	36.50	59.05	2.61	0.81	14,450	15,000	
Pittsburg, Pa.	Bitu.	1.37	35.90	52.21	8.02	1.80	13,410	14,800	
Hocking Valley, Ohio	Bitu.	6.59	34.97	48.85	8.00	1.59	12,130	14,200	
Big Muddy, Ill.	Bitu.	7.50	30.70	53.80	8.00		12,400	14,700	
Carterville, Ill.	Bitu.	4.87	34.11	52.17	8.85	0.85		14,150	
Wisconsin Average	Peat		56.4	24.0	19.5	0.55	8,070		Average sample for dry fuel.
Whitewater, Wis.	Peat	14.00	51.35	25.28	9.37		7,396	9,695	Aid dried briouette.
Fond du Lac	Peat	15.89	44.96	23.49	15.66	0.74	6,975		Air dried machined peat.

TABLE 32

Comparison of Wisconsin Peat With Various Coals Commonly Used in Wisconsin

Ultimate Analysis

Locality	Class	C	H	O	N	S	Ash	B. T. U. Per Lb.	Remarks
Pennsylvania	Anthra.	91.50	3.50	2.60				15,200	
Pittsburgh, Pa.	Bitu.	76.05	5.07	8.11	1.01	1.62	8.11		
Hocking Valley, Ohio	Bitu.	72.29	6.53	8.28	1.50	0.43	2.72	13,400	
Big Muddy, Ill.	Bitu.	69.90	5.26	8.35	1.33	2.02	6.90	12,600	
Wisconsin Average	Peat	46.30	4.60	26.40	2.35	0.55	19.50	8,070	Average sample.
Fond du Lac, Wis.	Peat	47.14	4.42	27.45	2.95	0.74	17.30		Dry Fuel.

Price

Data concerning the cost and selling prices of Wisconsin peat are rather meager. The only two sources from which these could be obtained, the Fond du Lac and Whitewater factories, are not now in operation and exact data are not available. The cost of manufacture of the product of these plants is understood to have been in the neighborhood of $2.00 per ton, while the selling price was from $3.00 to $6.00 per ton. Some local demand for this peat at these prices was developed while the factories were in operation.

Quantity of Peat in Wisconsin

It is rather difficult to make even an approximate statement of the total quantity of peat available in Wisconsin for commercial purposes. No complete data are at hand for the determination of this amount.

Professor T. C. Chamberlin in his reports on the Geology of Wisconsin estimates the available quantity of dried peat in the state to be 50 million tons. This estimate is based upon data gathered during an investigation of the geology of the state. But Chamberlin's work relative to the peat deposits was limited and this estimate is probably much too low.

F. H. King, in the "Handbook of Northern Wisconsin," states that "while there are but few very large areas continuously covered by these soils, yet the aggregate amount of them in northern and central Wisconsin is very large, probably not less than 1 to 1.5 million acres." This estimate probably was not intended to include the peat deposits of southern Wisconsin.

L. S. Smith, in "Water Powers of Wisconsin," writes, "Many of the northern swamps are underlain by vast beds of peat, while all have a thick covering of moss and humus." "The aggregate amount is probably not less than 2,500,000 to 2,800,000 acres."

No official survey of the quantity of peat land in Wisconsin has ever been made, but there are somewhere between two and three million acres.

In the following table (Table 33) are given data for the various Wisconsin bogs prospected in 1903 and 1908. An inspection of this table will reveal some interesting figures. Deposits 1 to 17, inclusive, were prospected in 1903; those numbered 301 to 333, inclusive, during 1908.

TABLE 33

TABLE GIVING ESTIMATES OF AREA, DEPTH, AND QUANTITY OF PEAT IN DEPOSITS PROSPECTED

Deposit No.	Location	Area In Acres	Depth In Feet	Acre-feet	Tons of Finished Peat
1	Stoughton	520	9	4,680	936,000
2	Whitewater	640	9	5,760	1,152,000
3	Whitewater	200	7	1,400	280,000
4	Whitewater	12,800	5	64,000	12,800,000
5	Lake Beulah	500	12	6,000	1,200,000
6	Dousman	9,600	3	28,800	5,760,000
7	Madison, Lake Wingra	100	2.5	250	50,000
8	Glen Beulah	9,600	9	86,400	17,280,000
9	Medina	6,400	6–14–(Av.12)	76,800	15,360,000
10	Eldorado	4,000	8	32,000	6,400,000
11	Chester	32,000	6	192,000	38,400,000
12	Mendota	1,300	10	13,000	2,600,000
13	Markesan	....	12	....	....
14	Marshall	....	....	....	....
15	Rhinelander	1,200	6	7,200	1,440,000
16	Camp Douglas	2,000	2	4,000	800,000
17	Babcock	....	....	....	....
301	Mendota, Yahara River	500	7	3,500	700,000
302	Madison, University Bay	100	6	600	120,000
303	Fond du Lac	800	7	5,600	1,120,000
304	Waupaca	1,500	6–17–(Av.10)	15,000	3,000,000
305	Waupaca	60	20+	1,200	240,000
306	Kiel, Manitowoc	10,000	8	80,000	16,000,000
307	Kiel, Manitowoc	....	....	....	....
308	Kiel	....	6	....	....
309	Kiel, Sheboygan	5,500	4	22,000	4,400,000
310	Bloomer	2,000	3	6,000	1,200,000
311	Bloomer	10	6	60	12,000
312	Ashland	80	8	640	128,000
313	Hayward	40	16	640	128,000
314	Hayward	200	10	2,000	400,000
315	New Auburn	1,000	8	8,000	1,600,000
316	Cameron	500	14	7,000	1,400,000
317	Ladysmith	40	4	160	32,000
318	Heafford Jct	80	20	1,600	320,000
319	Minocqua	40	6	240	48,000
320	Minocqua	80	16	1,280	256,000
321	Lac du Flambeau	15,000	4	60,000	12,000,000
322	Powell	100	8	800	160,000
323	Glidden	300	14	4,200	840,000
324	Park Falls	60	5	300	60,000
325	Kewaunee	800	6	4,800	960,000
326	Algoma	30	3	90	18,000
327	Sturgeon Bay	150	14	2,100	420,000
328	Peshtigo	500	2	1,000	200,000
329	Pembine	80	6	480	96,000
330	Gagen	200	9	1,800	360,000
331	Eagle River	500	9	4,500	900,000
332	Antigo	50	1.5	75	15,000
333	Mountain	60	3.5	210	42,000
50	Totals	121,220	....	758,165	151,633,000

NOTE:—Area in acres is a rough estimate based on observations and not on measurement.
Depth in feet was determined by soundings.
In computing "Tons of Finished Peat", the constant 200 tons per acre-foot was used. See p. 70.

The following figures are shown:

Total number of deposits prospected	50
Total area in acres	121,220
Total amount of peat, acre-feet	758,165
Total finished peat available, tons	151,633,000
Minimum area of deposit, acres	10
Maximum area of deposit, acres	32,000
Minimum depth of deposit, feet	1.5
Maximum depth of deposit, feet	over 20
Minimum tons in deposit	12,000
Maximum tons in deposit	38,400,000
Average depth $\frac{758,165}{121,220}$, feet	6.25

The area of peat land actually tested in the surveys covered by this report is estimated as 121,220 acres. The bogs tested are capable of yielding at least 151,600,000 tons of air-dried machine peat, which, at $3.00 a ton, represents a value of 155 million dollars.

About one in every ten or fifteen deposits was examined, so that the total peat resources of the State have a value of probably ten times these figures. It is estimated that there are between two and three billion tons of peat in Wisconsin.

Approximate Chemical Change of Vegetation into Peat

An interesting line of study is suggested in connection with the approximate chemical changes which Wisconsin peat undergoes in its transformation from woody fibre into peat. The available ultimate analyses of Wisconsin peat were arranged in the order of the heating value of the several samples in Table 34, so that the relations existing, if any, might be brought out.

TABLE 34

Approximate Chemical Change of Vegetation into Peat

Location	No.	Type	Texture	Dry Fuel						
				B.T.U.	C	H	O	N	S	Ash
Waupaca	305	Sphagnum bog	Spongy, moss-like light-brown and algal.	7,465	40.26	4.94	25.10	2.83	0.70	26.17
Pembine	329	Cedar Swamp	Dark-brown, fibrous.	7,835	46.84	4.49	26.56	1.71	1.67	18.73
Fond du Lac	303 B	Sedges and grasses	Black and somewhat fibrous.	8,149	47.14	4.42	27.45	2.95	0.74	17.30
Hayward	313	Tamarack and Cedar Swamp.	Dark-brown, fibrous.	8,761	51.00	4.71	26.54	1.92	0.29	15.54

Further, a chart was prepared from Table 34 (See Figure 10) which shows these relations graphically. There are but four analyses from which to construct curves and, therefore, the evidence is not complete nor conclusive. Nevertheless, the following points may be noted.

As the decomposition of the material progresses from the younger and poorer type of sphagnum peat to the older and more decomposed cedar and tamarack swamp types, there is a noticeable increase in carbon content, thus showing plainly the conversion of the material into carbon. There seems to be a reduction in the hydrogen content, while the oxygen content increases at first and then decreases. Nitrogen and sulphur undergo practically no change. The chart further shows that the samples having the greatest heating values also have the highest percentages of carbon and the lowest percentages of ash.

This table and chart should be compared with similar data in Chapter I. Further study of this question would, no doubt, show additional points of interest.

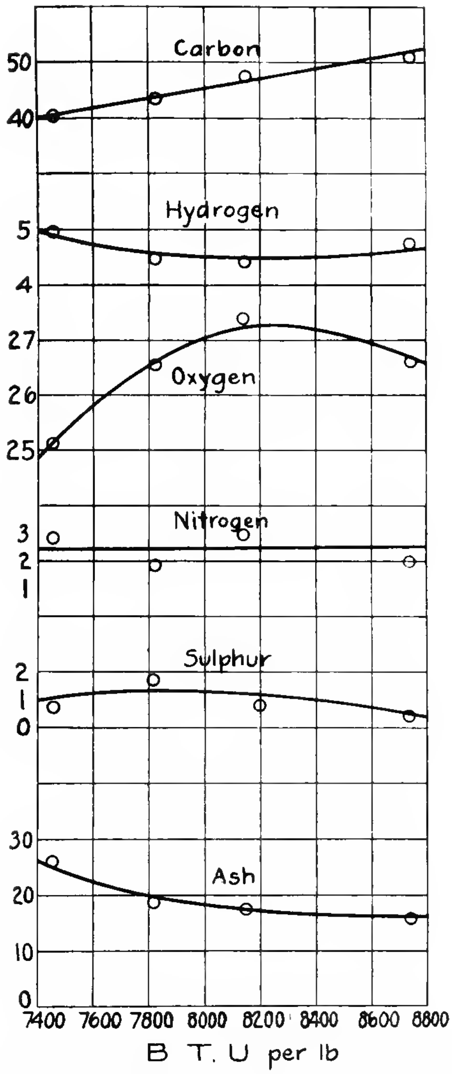


FIG. 10. APPROXIMATE CHEMICAL CHANGE OF VEGETATION INTO PEAT

PART III

ATTEMPTS TO DEVELOP WISCONSIN PEAT DEPOSITS

The Use of Peat in Wisconsin

The utilization of Wisconsin peat commercially is not a new problem in this state. As far back as 1868 an attempt was made to place it upon the market and since that time other attempts have been made to utilize it commercially.

It is quite a common thing to find people who remember having seen peat used for domestic purposes by some of the early settlers of Wisconsin. It was no uncommon thing for farmers to use peat which was dug from some bog near their farms. The peat, dug from the bog with spades, shovels, or special peat knives called "slaynes," was spread upon the ground in slabs as cut and allowed to dry while exposed to the sun and air. After drying, it was in condition for use as a fuel. Many farm homes were thus supplied with enough fuel for the entire winter, the peat being dug and prepared during the summer months. Indeed, as late as 1907, Dr. Samuel Weidman, of the Wis. Geol. & Nat. Hist. Survey, wrote in his report on, The Geology of North Central Wisconsin, "Crude peat, cut in blocks out of the bog and dried in the open air, after which it is burned without further treatment, has been observed by the writer in southeastern Portage county."

That this should have been the case is quite natural. Many of these settlers came from such countries as Ireland, Germany, and the Scandinavian countries where peat had been used as fuel for centuries. They had actually seen peat used, indeed, had used it themselves and were led to do likewise in Wisconsin. But, on account of the ease with which large quantities of wood were obtainable from the near-by forests, the use of raw peat in this manner never assumed large proportions and was confined to local use, chiefly by farmers.

Besides having been utilized for fuel purposes, Wisconsin peat has been used to some extent for fertilizing lands. But its use in this manner was limited. T. C. Chamberlin, in Geology of Wisconsin, Vol. 2, p. 245, in writing on the geology of eastern Wisconsin says, "Peat has been used in this region to some extent as a fertilizer, and always with good results. Its value is much increased when mingled with other kinds of fertilizers, and it is especially efficient in absorbing the liquid manures that are usually wasted. The good results

of the few trials that have been made, corroborated as they are by experience elsewhere, and justified by reasoning from the nature of peat, commend this subject to the earnest attention of our agriculturists."

The use of peat, however, never was extensive nor regular, and, in fact, never passed out of the experimental stage. Peat fuel factories have been built and operated for a time, but all are now closed indefinitely. Interest in these is revived from time to time as new operations are projected and announced but at present the peat industry in Wisconsin is practically dormant.

The attempts at development of Wisconsin peat have been mainly along the lines of utilizing it for fuel, gasifying it, and manufacturing it into paper. Some of the work which has been done along these lines, as well as some which is projected, is briefly described in Part III.

PHOTOGRAPH SHOWING THE EXPERIMENTAL PEAT GAS PRODUCER PLANT AT THE UNIVERSITY OF WISCONSIN

For a description of this plant see text.

CHAPTER VIII

THE MANUFACTURE OF PRODUCER GAS FROM WISCONSIN PEAT

Gas from Peat

Some experimental work was done at the University of Wisconsin in 1903 by Johnson and Hadfield in the production of gas from Wisconsin peat by the retort method. A gas was obtained which, when burned in a Welsbach lamp, gave a light fully equal to that of the ordinary city illuminating gas. In 1904 further work was done on the distillation of Wisconsin peat by Benedict and Saradakis. (See Chapter IX). But the capacity of the apparatus was so small that the gas could not be generated fast enough to supply the requirements if used in a commercial way. The work described in the present chapter relates to the generation of gas from peat on a commercial scale by means of the producer method.

This description is largely an abstract of the thesis of S. W. Cheney and L. B. Moorehouse, written in 1904 and entitled, "The Manufacture of Producer Gas from Peat." Most of the material is taken directly from the thesis.

The first problem which presented itself was that of the design of an apparatus suitable for the continuous manufacture of gas in such quantities as would be required by a gas engine, for instance, sufficiently large for a practical commercial test. This was attempted by the gas producer method, a method employed extensively and with much success in the manufacture of producer gas from coal.

The general design of a producer using peat was taken from some of the producers commonly used for coal, a few modifications being made to meet special requirements. The modern gas producer plant as it is now used and the method of gas production by it may be understood from the following description.

A Gas Producer Plant

The producer proper is, as its name implies, the part of the apparatus in which the principal chemical changes take place in the fuel to produce the gas. It consists of a vertical, cylindrical furnace,

the height of which is four or five times the diameter, and is lined with fire brick the entire height. Near the bottom is a grate which allows the ashes to be shaken through. The producer is arranged so that fuel may be fed in at the top and the ashes removed at the bottom without opening up the interior of the producer. A pipe carrying compressed air and one carrying steam are run in at the bottom to furnish blast to the fuel bed.

In the production of the gas there is a thick bed of ashes on the grate; above this is a bed of fuel, in which there is a zone of incandescence next to the ashes, and just above this is a zone in which the fuel is cooler, varying from a black to a dull red color. The blast of air, or air and steam, is blown up through this from below, burning the fuel in the incandescent zone to $C\ O_2$, this passing on upward and, as it reaches the cooler fuel above, it takes on another atom of C, changing it to $2\ C\ O$. This is the principal combustible part of the gas, being about 25 per cent to 30 per cent by volume of the final product. There are also formed $C\ H_4$, $C\ O_2$, free H (and, of course, free N from the air used in the blast).

A good producer gas consists of the following constituents:

	Approximate % By Volume
Carbon Monoxide, CO,	27.0
Hydrogen, H,	12.0
Methane, CH_4,	2.5
Carbon Dioxide, CO_2,	2.0
Nitrogen, N,	56.5
Total	100.0

When air alone is used as a blast in the producer, the amount of free Hydrogen (H) is materially reduced.

From the producer the gas enters a superheater and economizer through which the pipes of the air-blast of the producer pass, the blast becoming heated thereby. Next, the gas passes to the wash-box where the tarry matter, etc., is deposited. Here also is arranged a seal against the gases stored in the holder and present in the rest of the apparatus. The gas now passes to the scrubber which is filled with coke, and showered by means of water sprays and further purified of any tarry matter, sulphur or ammonia. This operation is completed in the purifier which contains lime and iron oxide. This is the last element of the plant before reaching the holder.

The holder is the common gas holder made gas tight by inverting a large sheet-iron tank-like vessel in another which is filled with

water. The inverted portion is counter-balanced so that it will move up and down and constantly maintain the desired uniform pressure.

Ordinary producer gas averages about 150 B. T. U. per cubic foot, this being from bituminous or soft coal and containing more hydrocarbons than that from anthracite or hard coal and consequently having a higher calorific power. Anthracite coal producer gas shows a calorific value of about 110 B. T. U. per cubic foot.

The Experimental Plant

The apparatus as used in this research work consisted principally of; (1) the producer proper, (2) the water seal, (3) the washer, (4) the drier, and (5) the storage tank.

It was not thought practical or necessary to use an economizer, as the principal object of the work was to ascertain whether a good gas could be obtained from peat by the producer method, and economy was considered secondary in the present work. Also, the wash-box and scrubber were combined into one piece of apparatus, this being entirely sufficient for the work.

Fig. 11 shows a vertical cross-sectional view of the producer as used. The body is constructed of tank steel ¼-inch thick and has a lining of fire-brick, 4 inches thick, the full height of the main body. The shell of the main body is 2 feet, 8 inches in diameter and is 10 feet high. The fire-brick on the inside reduces the internal diameter to 2 feet.

At the bottom and in front is an opening, 12 inches wide by 22 inches high, for the purpose of removing ash and clinker. This opening has an air-tight cover which is used when the producer is in operation. The drawing does not show this opening.

In the side, near the top, is an opening from which is led a 4-inch wrought-iron pipe for the outlet of the gas. This is shown at A in the figure.

On top, the shell is carried upward a distance of 18 inches and of a diameter of 2 feet corresponding to that inside the fire-brick below. In this top extension there is a removable bottom, B, which rests on a projection, C, and has a number of holes, 1 inch in diameter, drilled in radial rows through it. On this rests another circular plate having corresponding holes through it and having a vertical spindle, D, fastened to the center of it in order that it may be rotated by a lever, E. The lever, E, is fastened to an extension of the spindle, D, at the top. The two parts of the spindle fit together by

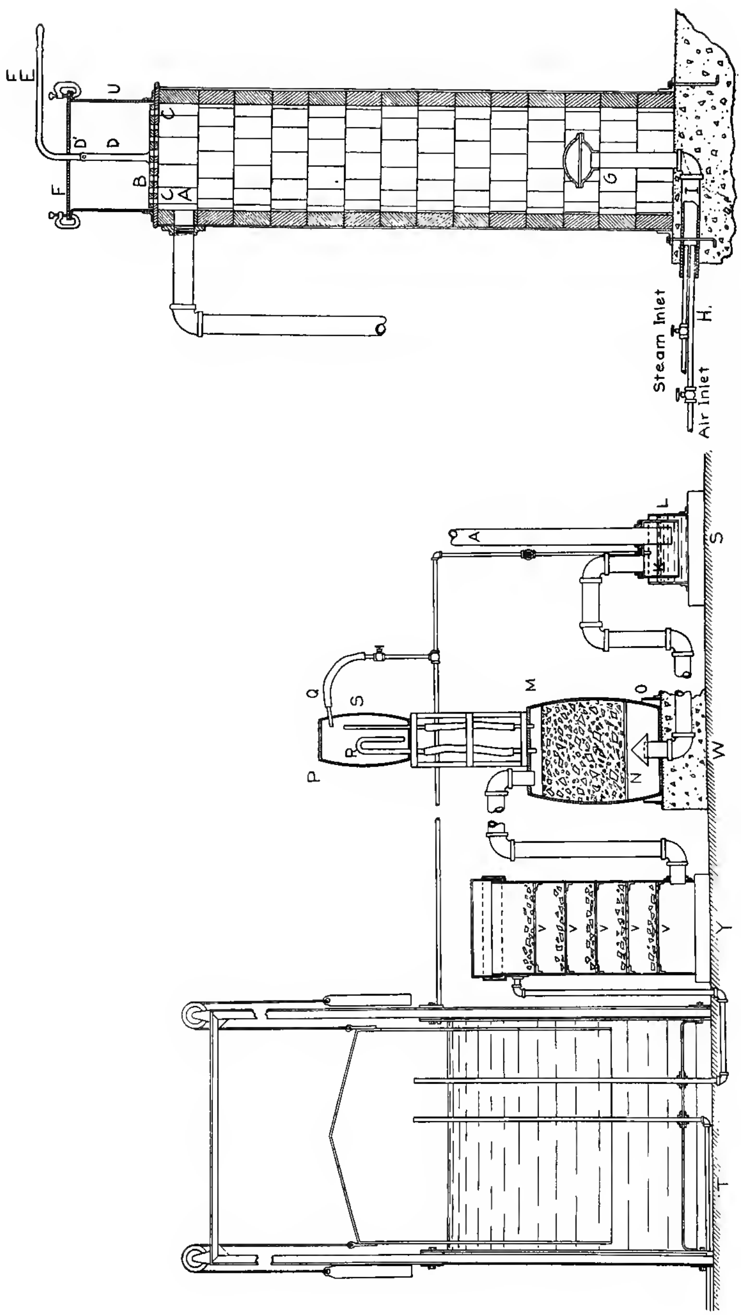


FIG. 11. EXPERIMENTAL GAS PRODUCER PLANT FOR PEAT

means of a pin and slot. The part of the spindle fastened to the lever passes air-tight through the top, F, which top is a flat circular plate. Top, F, can be clamped to the upper cylinder, U, and can be made practically air-tight by means of packing.

By this arrangement the holder can be filled with fuel and this can be shaken down and spread evenly on the fire below. Also, the top can be removed to fill the holder without removing the bottom on which rests the fuel.

At a distance of one foot above the bottom of the producer is placed a circular steel plate, G, upon which rests the ashes, thus forming an air space below. There is a pipe, H, led into the conduit, I, below, which furnishes compressed air for a blast.

The foundation upon which the producer stands is of concrete 4 feet square and 1 foot deep. There are anchor straps which are embedded in the concrete and at the upper end are bolted to the steel shell of the producer.

The gas pipe, A, leads into the water seal, S, (Fig. 11), which is for the purpose of preventing a back flow of the gas in case the producer is opened during the process.

It consists principally of two cylindrical flat-topped vessels, K, and L, of galvanized sheet-iron, K, being somewhat smaller in diameter and inverted in L. The gas pipe, A, from the producer runs through the top of K, and down to within 1 inch of the lower edge. The gas pipe to the washer runs out of the top of K. There is water in L, to such a depth that when there is a pressure of 3½ inches of water in the holder there will be a seal of ¾-inch of water over the lower end of the gas pipe, A.

The washer, W, (Fig. 11), was made from a common oil barrel, there being a false bottom made of perforated tin plate at M, and one of wood at N, through which were bored a number of holes ½-inch in diameter. The space between these false bottoms is filled with coke and there is an intermittent spray of water from above, which trickles down through the coke and into the pan, O. By this means, a water seal is maintained on the lower end of the barrel. The gas in passing through the washer deposits its tar, etc., on the wet coke and this is washed away by the water.

The intermittent spray is brought about by the siphon arrangement in the keg, P, supported at a small distance above the top of the barrel. At Q is the inlet pipe for the water, and R, is a siphon-shaped pipe which empties the keg when the water reaches the top of the bend. As this empties the keg faster than the water flows in, the flow into the washer becomes automatically intermittent. The

connection at S, is to equalize the pressure in the washer and the keg.

The gas goes from the washer into the drier, Y, (Fig. 11), which is a galvanized iron tank having five shelves, V, upon which there is placed quick-lime, this being for the purpose of further drying and purifying the gas.

The gas-holder, T, (Fig. 11), is essentially the same as the common gas holder, having one part inverted in the other which is filled with water.

Connections with a water supply were made to the washer and to the water seal, both having valves to control the flow.

It will be seen from the description that this is a Gas Producer of the Pressure Type.

Plate XVI shows a photograph of the apparatus.

Tests of the Producer Plant with Coke

In order to test the apparatus with a fuel which had before been used successfully to produce gas, the producer was fired up with a charge of common gas coke, the thickness of the fuel bed being about 12 to 18 inches. This fuel bed was heated up to a bright red heat by means of the air blast and then the cover was placed in position. The blast was continued, the gas formed passing through the apparatus into the holder.

The gas thus manufactured would not burn at atmospheric pressure and, when it was analysed with an Orsat apparatus, it showed a large amount of Carbon Dioxide ($C\,O_2$) but a small percentage of Carbon Monoxide ($C\,O$) which is the principal combustible of producer gas. From the observations made it was thought best to increase the depth of the fuel bed and the zone of incandescence.

The fuel bed was increased to a thickness of about 3 feet and was heated until nearly the entire bed was incandescent The apparatus was closed up and the air run through as before and the holder filled. This gas was much better than the first and when tested at the nozzle would burn and an analysis showed a much higher percentage of Carbon Monoxide ($C\,O$) and a low percentage of Carbon Dioxide (CO_2).

Quality of Gas Obtained Using Coke as Fuel

The results showing the quality of the gas obtained from this producer when coke was used as a fuel are given in the following tables.

TABLE 35

VOLUMETRIC ANALYSIS OF GAS MADE FROM COKE
Fuel bed 12 inches to 18 inches thick

Test No.	% of CO_2	% of O	% of CO
1	2.2	3.8	6.6
2	0.9	1.1	6.4
Average	1.55	2.45	6.5

TABLE 36

VOLUMETRIC ANALYSIS OF GAS MADE FROM COKE
Fuel bed 3 feet thick.

Test No.	% of CO_2	% of O	% of CO
1	6.0	0.3	25.5
2	1.3	0.1	26.9
3	4.5	0.2	25.1
Average	3.93	0.2	25.85

TESTS OF THE PRODUCER PLANT WITH PEAT

Peat was next used in the same manner as the coke, the fire being started with common coke and peat put in afterward. The bed was blasted up in this test until most of the volatile matter was driven off in a thick tarry smoke and it commenced to burn with a reddish transparent flame issuing at the top. The producer was then closed up and gas generated.

Two trials were made, each upon a different day. In both trials the volumetric analysis of the gas was made with a Hempel apparatus, Methane ($C\ H_4$) and Hydrogen (H) being determined by the explosion method.

Different samples of peat were used in the different trials and the tests show some difference in the contents and the calorific power of the gas produced. Test No. 1 also seems to show a lower temperature of formation as there is more $C\ O_2$, more of the higher hydrocarbons, such as $C\ H_4$ and $C_n\ H_{2n}$ and less C O and H.

Quality of Gas Obtained Using Peat As Fuel

TABLE 37

Test No. 1 With Peat

Volumetric analysis of gas made from peat, May 6, 1904.

Constituents	% By Volume	B. T. U. In Cu. Ft. At 60°	B. T. U. In Specimen
CO_2	6.0	....	....
C_nH_{2n}	0.8	1,558.0	10.47
C_6H_6	0.0	....	....
O	0.0	....	....
CO	17.9	323.5	57.90
CH_4	6.23	1,009.0	62.80
H	18.07	326.2	59.00
N	51.00	....	....
Totals	100.00	....	192.17

The heating value of this gas, determined by means of a Junker's Calorimeter, was 199.6 B. T. U. per cubic foot at 60° F.

TABLE 38

Test No. 2 With Peat

Volumetric analysis of gas made from peat, May 10, 1904.

Constituents	% By Volume	B. T. U. In Cu. Ft. At 60°	B. T. U. In Specimen
CO_2	1.3	....	....
C_nH_{2n}	0.5	1,558.0	7.78
C_6H_6	[illegible]	....	....
O	0.0	....	....
CO	20.7	323.5	62.00
CH_4	3.22	1,009.0	32.50
H	20.39	326.2	66.40
N	53.69	....	....
Totals	100.00	....	168.68

The heating value of this gas, determined by means of a Junker's Calorimeter was 182.2 B. T. U. per cubic foot at 60° F.

The Use of Producer Gas from Peat in Gas Engines

An attempt was made to use this gas in a Cavanaugh and Darley gas engine. The engine had a compression of about 45 pounds per square inch as set up, and this was increased to about 55 pounds per square inch by lengthening the connecting rod.

The engine was started on the gas from the city mains and then, by means of a three-way cock, the gas from the experimental plant was turned on in place of the city gas. The engine when running without load seemed to work moderately well, but the action seemed to indicate that the mixture was not rich enough, and that the compression was too low, as the engine would not develop any power when a brake was applied.

There seems to be every reason to believe that an engine with a higher compression and the proper gas mixture could be made to run efficiently on this gas.

Conclusion

The experiments described in this chapter, though incomplete and not very extensive, show that a good producer gas can be made from Wisconsin peat. They also serve to point out possibilities in the utilization of peat producer gas in industrial operations of various kinds and particularly in the generation of light, heat and power.

CHAPTER IX

THE PRODUCTS OF DISTILLATION OF WISCONSIN PEAT

Introductory

The work described in this chapter is the outcome of an attempt to determine the composition of the various gases that are derived from Wisconsin peat by destructive distillation. This description consists largely of an abstract of the thesis of W. J. Benedict and F. J. Saradakis, written in 1904, entitled "An Analysis of the Products of Distillation of Wisconsin Peat." The samples of peat used for these tests had been exposed to the air of the laboratory for some time and, consequently, contained about as much moisture as would be found in the peat bricks air-dried and stacked by farmers for home use. The amount of moisture present was usually from 10 to 15 per cent by weight.

While these experiments in themselves are not complete nor conclusive, they serve to point out some interesting possibilities along the lines of gas manufacture from peat. Lack of time prevented repetition and thorough checking of these results and further experiments are therefore necessary before the evidence given in this chapter may be accepted as final.

First Apparatus

The apparatus originally used for distilling the peat consisted of a sheet-iron generator, a glass, water-cooled, condenser, a glass oxide-purifier, and a water-sealed gas tank, arranged as shown in Fig. 12.

The gas was driven off from the peat at a good high temperature furnished by a group of Bunsen flames placed under the generator, A, and it went from the generator to the condenser, B (See Fig.12), where the moisture and tar and oils were condensed. From the condenser the gas passed on to the scrubber, C, which was filled with powdered ferrous oxide mixed with crumbs of corn cobs, saw dust, and so forth, so that the gas might be brought into intimate contact with the oxide and yet not have its passage obstructed. The iron oxide was introduced to remove any inorganic compounds which might be present in the gas. After passing through the scrubber,

the now thoroughly purified gas was piped to the water-sealed gas holder, a sheet-iron tank of considerable capacity.

It seemed, at the outset, as if this apparatus might prove very satisfactory, but it was found that the generator was out of proportion to the tank, being altogether too small. Moreover, the tank

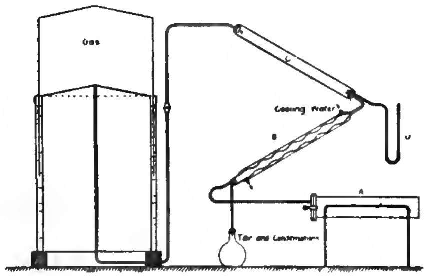


FIG. 12. FIRST ARRANGEMENT OF APPARATUS FOR DISTILLING GAS FROM PEAT

was too large to act as a container for gas for testing purposes, as only small amounts were needed; and the small amount of gas in the tank, coming in contact with the large volume of water, was robbed of much of its Carbon Dioxide, and therefore, a test of the gases, after a few hours storage in the tank, could not be a true test of the gases as distilled over from the peat.

Results of Tests With First Apparatus

Results from tests made on gas, obtained as described above, follow:

TABLE 39

Volumetric Analysis of Gas Made From Peat

Constituent Gas	Per Cent Volume					
	Test 1	Test 2	Test 3	Test 4	Test 5	Test 6
CO_2	50.1	59.3	51.7	83.8	77.2	47.4
C_nH_{2n}	0.5	4.2	0.6	0.4	0.3	1.2
C_nH_n	0.2	1.7	0.2	0.2	0.4	0.5
O	1.7	1.2	1.1	0.3	0.0	1.2
CO	23.7	10.3	15.3	6.6	9.1	16.8
CH_4	8.7	11.2	14.4	....	....	16.3
H	6.8	6.6	11.6	....	....	11.0
N	8.3	5.5	5.1	....	....	5.6

The peat used in the above tests was dried at the Whitewater Peat Company's factory and had the following composition by weight.

Proximate Analysis of Whitewater Peat

	As Received	Dry Fuel	Combustible
Moisture per cent	15.4	....	....
Volatile Matter, per cent	52.2	61.6	67.8
Fixed Carbon, per cent	24.9	29.4	32.2
Ash, per cent	7.5	9.0	....

Second Apparatus

On discovering that the apparatus in use was not such as to allow perfect tests of the gas, a new and much more simple arrangement was made (see Fig. 13) whereby the gas was generated and then run directly into a flask filled with water, displacing the water which was forced over into a beaker and which served as a water seal for

the gas in the flask. By this method but little carbon dioxide could be lost by absorption into the water as the water was used over and over again, and soon became saturated.

It was found, however, that the gas obtained by this arrangement was practically useless as a fuel gas. So great an amount (90.0 %) of carbon dioxide was present that the gas refused to burn. This high

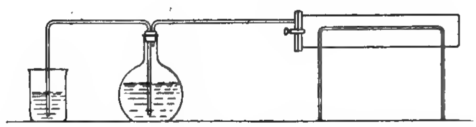


FIG. 13. SECOND ARRANGEMENT OF APPARATUS FOR DISTILLING GAS FROM PEAT

percentage of carbon dioxide was attributed to combustion in the retort due to local overheating, and it seemed evident that peat could never be successfully used as a source of illuminating gas unless a temperature could be determined upon, which would cause a more useful mixture of gases to come over as a result of destructive distillation. Both Whitewater and Lake Beulah peat were tried.

Third Apparatus

After repeated attempts to find a method of securing a uniform temperature which could be accurately regulated all over the surface of the retort, a metal bath was tried with most excellent results. (See Fig. 14). The bath was composed of bismuth and tin alloys of low melting points and with it the temperature could be regulated to a nicety and could be kept perfectly constant for hours at a time. The metal jacketed the retort and acted not only as a means of distributing the heat uniformly and preventing any one part from becoming over-heated, but it served as a heat reservoir and regulator, giving up heat whenever the pressure in the gas mains lowered, and absorbing it when the flame became too hot.

Results of Tests with Third Apparatus

With this apparatus it was found that gases are distilled out of the peat not all at once, but in a sort of succession. For instance, if the total gaseous content of a quantity of peat were distilled off and stored separately on coming over, the output of the first thirty

minutes being put into one reservoir, that for the next thirty minutes into another reservoir, and so on until the gas was totally exhausted from the peat, the contents of the several reservoirs would be found to vary greatly in composition.

When the experiment was tried the first flow of gas was found to be very high in carbon dioxide as the carbon dioxide comes off at

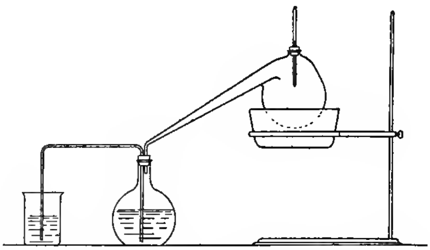


FIG. 14. THIRD ARRANGEMENT OF APPARATUS FOR DISTILLING GAS FROM PEAT

lower temperatures; and, hence, the earlier assumption, that the carbon dioxide came in great quantities from overheating, was proven false. As the process continued, the carbon dioxide decreased while the combustible gases, Hydrogen and Methane, increased rapidly in per cent of volume. From this it will be seen that peat gas becomes richer as the process of distillation progresses.

Several fractional distillations were carried through with peat samples from various localities. The results obtained from good grades of peat show a uniformity of succession in separating.

The tests of Lake Beulah peat given below serve to show this succession of gases in coming over.

TABLE 40

SUCCESSION OF GASES FROM LAKE BEULAH PEAT

Constituent Gas	Per Cent of Volume		
	Part 1	Part 2	Part 3
CO_2	63.8	45.8	36.7
C_nH_{2n}	0.2	0.8	2.7
C_nH_n	0.0	0.4	0.0
O	2.0	1.6	0.8
CO	17.8	17.6	19.6
CH_4	3.7	15.5	19.2
H	2.8	14.3	16.9
N	9.7	4.0	4.1

PROXIMATE ANALYSIS OF LAKE BEULAH PEAT

The peat used in these tests had the following composition.

	As Received	Dry Fuel	Combustible
Moisture, per cent	11.9	......	......
Volatile Matter, per cent	48.2	56.7	64.7
Fixed Carbon, per cent	26.3	30.9	35.3
Ash, per cent	10.6	12.4	......

TABLE 41

SUCCESSION OF GASES FROM ROCK LAKE PEAT

Constituent Gas	Percentage of Volume				
	1	2	3	4	5
CO_2	86.2	56.8	43.6	27.6	25.4
C_nH_{2n}	1.2	4.6	2.4	2.4	1.0
C_nH_n	0.2	1.4	1.5	0.0	0.0
O	0.0	0.2	0.1	0.2	0.2
CO	8.6	11.6	9.3	4.6	4.7
CH_4	......	13.1	22.7	34.3	36.0
H	......	11.4	19.3	30.4	29.8
N	......	0.9	1.1	0.5	2.9

From the above results it may be seen that the peat gas contains a great variety of gases and that the mixtures distilling off at different stages of the decomposition are of different composition. But, from the standpoint of the gas industry, the question is not whether the gas at one stage or another is a good combustible gas. It is more important to know whether the total product of complete distillation makes a good burning gas, for there would be no economy in a process in which a large fraction of the product had to be thrown away.

To determine the products of total destructive distillation, several lots of peat were distilled until no more gas came off and the products were analysed separately. The results of the analyses, given below, show a gas rich in combustible material, for it averages from 25 per cent to 30 per cent Hydrogen and 30 per cent Methane.

TABLE 42

TOTAL GAS FROM ROCK LAKE PEAT

Constituent Gas	Percent of Volume			
	Test I	Test II	Test III	Average
CO_2	30.9	34.2	33.1	32.7
C_nH_{2n}	1.6	2.4	1.3	1.8
C_nH_n	0.2	0.2	0.4	0.3
O	0.3	0.0	0.1	0.1
CO	10.1	7.7	6.8	8.2
CH_4	30.3	27.9	30.1	29.4
H	25.7	26.8	27.7	26.8
N	0.9	0.8	0.5	0.7

HEATING VALUE OF THE GAS

As computed from the chemical analysis of the average sample, the heating value of the gas is about 475 B. T. U. per cubic foot. When compared with city gas whose heating value approximates 600 B. T. U., the heating value of this peat gas is low. But it must be remembered that nearly all of the CO_2 is removed from city gas while the peat gas obtained in these experiments contains 33 per cent of Carbon Dioxide. Removal of the CO_2 from peat gas would greatly increase its heating value.

Luminosity of Peat Gas

Tests of the luminosity of the peat gas flame showed that there was very little incandescent material in the flame and for that reason it gave but little light. When tried in a Welsbach burner, however, the heat of the flame was sufficient to heat the mantle to incandescence and produce an excellent light.

CHAPTER X

WISCONSIN PEAT AND ITS BY-PRODUCTS

Introductory

In this chapter is given a description of certain forms of apparatus used for the distillation of peat. Also, experiments and results relating to the gas and by-products obtained from peat are shown. In the preparation of this chapter the thesis of E. L. Leasman, "Wisconsin Peat and Its By-Products," written in 1907, was consulted and abstracted. In Mr. Leasman's experiments, efforts were made to study peat gas and its by-products with apparatus more nearly approaching commercial magnitude than that shown in Chapter IX. The data presented here are, therefore, probably more nearly accurate than those shown in the previous chapter.

Fields for the possible utilization of peat are pointed out.

Description of Apparatus

Retort

The retort consisted of a wrought-iron pipe six feet long and six inches in diameter, supplied with a cap on one end and a flange and cover at the other end. (See Fig. 15). It was bricked in with fire brick to within about four inches of the gas outlet pipe, and was built so that there was a space of an inch or more between the outside of the pipe and the interior of the brickwork.

The retort was heated by means of ten, four-burner Bunsen burners. These burners were protected from the heat by being passed through the two-inch openings of an iron plate on which the brickwork was built, and by means of sheet absestos.

The flange, against which the cover fitted, was supplied with a shallow groove, so as to make it possible to obtain an air-tight joint by means of an asbestos gasket placed between the flange and the cover. The cover was held tightly in place against the flange by means of a cotter-bar.

Gas Outlet Pipe and Hydraulic Main

The stand-pipe, or gas outlet pipe was made from a two-inch wrought-iron pipe. It was joined to the pipe, dipping into the water of the hydraulic main, by means of a union. A keg, lying on its side,

was used as a hydraulic main. All of the joints, where pipes passed into the keg, were made tight by screwing the threads of the pipe into the wood of the keg. Besides the inlet and outlet pipes for the gas, the main was provided with a tar overflow pipe with its water seal, and also, with an inlet pipe for fresh water.

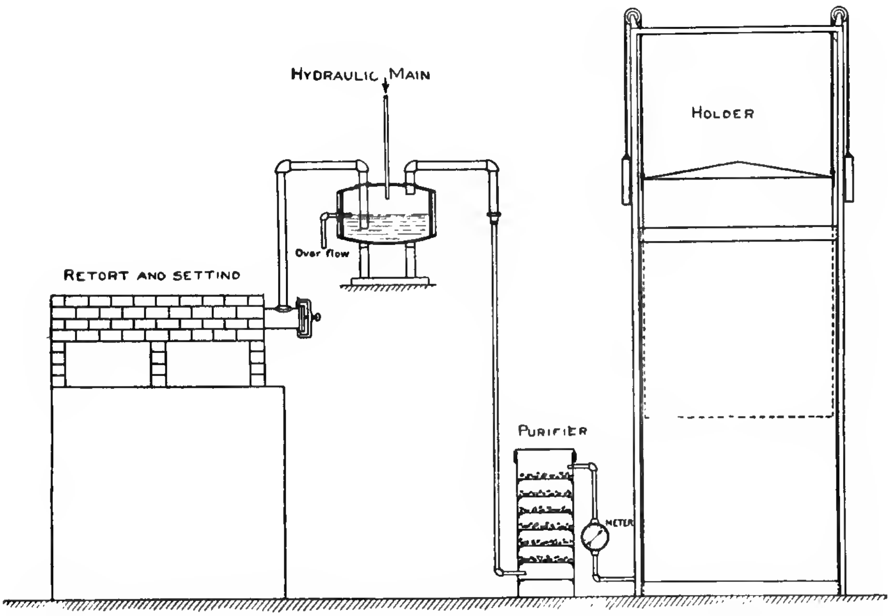


FIG. 15. EXPERIMENTAL PLANT FOR GENERATING GAS FROM PEAT BY THE RETORT METHOD

Gas Purifier

A $1\frac{1}{2}$-inch pipe, reduced to 1 inch, conducted the gas from the hydraulic main to the purifier. The purifier consisted of a rectangular galvanized iron box, about $3\frac{1}{2}$-feet long, $1\frac{1}{2}$ feet wide and 4 feet high. Trays, upon which fresh lime was placed, were provided. The amount of lime used was about one hundred pounds.

Gas Holder

An ordinary one-lift holder, having a capacity of about 100 cubic feet and provided with 2 ropes and counterweights, was used to store the gas made. The gas holder had inlet and outlet valves with necessary shut-off valves.

Exhauster

No exhauster was used, but the pressure was taken off of the retort by counter-weighting the holder lift so as to produce sufficient suction to handle the amount of gas made.

Meter

A ten-light dry gas meter was used to measure the amount of gas made.

Method of Operating the Plant

The hydraulic main was filled with water, so as to give the proper water seal to the dip pipe, the fire lighted, the retort rapidly charged by throwing in a weighed quantity of lump peat so as to be evenly distributed, the retort cover adjusted and sealed, and the distillation started. As soon as possible after charging the retort, the holder was counter-weighted to produce a suction, equivalent to 1 inch of water, on the system. The distillation was allowed to go on for three and one-half hours, when it was completed. At the expiration of this time the fire was extinguished, the valves of the retort were closed and the gas was allowed to stand in the holder until used.

Analysis of Peat Used

The peat charged into the retort was obtained from a factory formerly operating at Fond du Lac, Wisconsin. It had been cut from the bog, air dried, artificially dried and compressed. It came in lumps about the size of egg anthracite coal, and these lumps were very hard and tenacious and did not soil the hands on handling. The color of the peat was brown. It had the following composition:

Proximate Analysis

Moisture	13.00 %
Volatile Matter	46.32 %
Fixed Carbon	20.37 %
Ash	20.31 %

Ultimate Analysis

Carbon	48.82 %
Hydrogen	4.83 %
Nitrogen	2.45 %
Ash	20.95 %
Oxygen	23.95 %

Gas Made from Fond du Lac Peat

Slow Distillation

The peat described above was charged into the retort while the retort was cold and then it was gradually heated up to from 1,700 to 1,800 degrees Fahrenheit. Gas taken from the holder after having been stored for twenty-four hours gave the following analysis:

TABLE 43

Gas From Fond du Lac Peat. Volumetric Analysis in Per Cent Volume.

	I	II
CO_2	30.70	30.90
C_6H_6	0.20	0.20
Heavy Hydrocarbons	3.10	3.10
O	6.00	5.90
CO	9.40	9.50
CH_4	9.40	9.40
H	15.20	15.30
N	26.00	25.70

Gas Yield

The gas yield was 6.63 cubic feet per pound of peat.

Rapid Distillation

The analyses given below were obtained from gas which had been stored in the holder for about twelve hours. The gas was made by charging the peat into the retort after the retort had been heated to redness.

TABLE 44

GAS FROM FOND DU LAC PEAT. ANALYSIS IN PER CENT VOLUME.

	I	II
CO_2	33.00	32.80
C_6H_6	0.60	0.60
Heavy Hydrocarbons	6.00	6.20
O	2.50	2.40
CO	11.60	11.80
CH_4	13.90	13.90
H	21.02	21.02
N	11.38	11.28

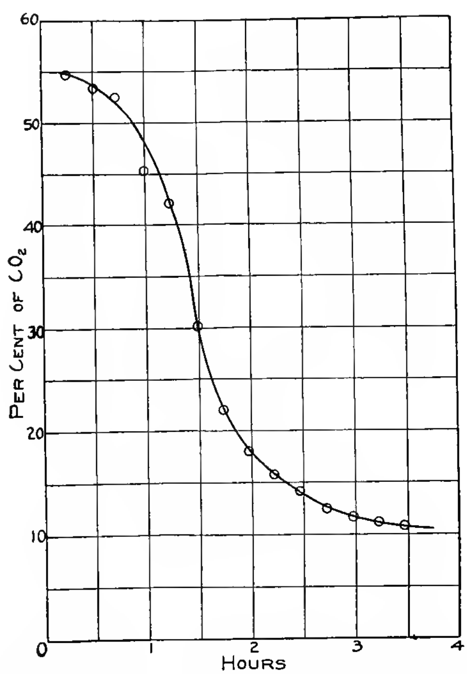


FIG. 16. CURVE SHOWING THE EVOLUTION OF CARBON DIOXIDE FROM PEAT

Formation of Carbon Dioxide

To show the rate of formation of carbon dioxide an analysis of the gas was made just before it passed into the holder, determining the carbon dioxide content only. Tests were made every fifteen minutes during the time of distillation, beginning fifteen minutes after the peat was charged into the retort. The curve on p. 200 gives a graphical record of the analyses and shows how the percentage of carbon dioxide varied as the distillation progressed. (See Fig. 16). During the first hour a very high percentage of carbon dioxide was evolved, during the next hour the percentage fell rapidly, and for the remainder of the time it became more constant. The slope of the curve during the last hour would seem to indicate that carbon dioxide would continue to be formed as long as any gas was made.

Partial Fractional Analysis of the Gas

The following partial analyses of the gas were made at the beginning, middle and end of the distillation. Samples were collected just before the gas reached the holder. The analyses show that the percentages of carbon dioxide, benzine, heavy hydrocarbons and oxygen grow less as the distillation progresses, while the carbon monoxide increases in amount.

ANALYSIS

Constituents	Beginning	Middle	End
CO_2	54.60	20.40	13.20
C_6H_6	4.60	3.00	0.00
Heavy Hydrocarbons	3.00	2.40	0.00
Oxygen	7.60	2.00	0.60
Carbon Monoxide	11.00	17.00	24.00

Complete Test of Gas

Another sample of the gas gave the following:

TABLE 45

Chemical Composition of Fond du Lac Peat Gas

Constituents	I	II
CO_2	27.00	26.80
C_6H_6	1.60	1.40
Heavy Hydrocarbons	2.50	2.60
O	4.80	4.80
CO	14.60	14.60
CH_4	17.93	17.93
H	21.24	21.24
N	10.33	10.63

Heating Value

The heating value of the above gas obtained by computation from the above analysis is 380 B. T. U. per cubic foot. Determined by means of Junker's Calorimeter it was 386 B. T. U. per cubic foot.

Illuminating Value

The lighting value of the gas was so small that its candle power was not determined. The presence of such high percentages of carbon dioxide, oxygen and nitrogen is, no doubt, accountable for the destruction of luminosity. However, the gas possesses sufficient calorific power to produce incandescence in a Welsbach mantle.

Yield

The gas yield per pound of peat was 6.70 cubic feet.

Peat Charcoal

General Characteristics. The charcoal obtained by the distillation of the lumpy Fond du Lac peat was hard, compact, did not

crumble on weathering and was black in color. Tiny cracks covered the surface of the charcoal. The peat did not cake but remained in individual lumps as charged. A white ash results upon burning the charcoal.

Yield. From a charge of seventeen and one-half pounds, the yield was seven and one-quarter pounds. This is about 41.6 per cent.

Heating Value. The heating value as determined by a Mahler's Bomb Calorimeter was 7,200 B. T. U. per pound.

Peat Tar and Gas Liquor

General Characteristics

The liquor found in the hydraulic main was reddish brown in color and had small brown and black particles floating in it. The amount of these particles per liter of gas liquor was very small and, when filtered and allowed to stand, they turned black and formed a tarry material which looked much like coal tar.

The gas liquor had a very offensive odor which resembled that from a strong tobacco pipe. The reddish-brown liquor was quite mobile. The black material was viscous and had an oily appearance. The specific gravity of the liquor, as it came from the hydraulic main, was 1.025. It was alkaline to litmus.

Fractional Distillation of the Liquor Found in the Hydraulic Main

When this liquor was distilled it was found that the fraction, distilled between the temperature of zero and 100 degrees Centigrade, was a cloudy looking liquid which was miscible with water in all proportions. On standing, the solution assumed a light straw color. This fraction began to distill at seventy-five degrees, but most of it came over at ninety-eight degrees Centigrade. On the top of the distillate, was found a brown, oily-looking liquid which was not miscible with the rest of the distillate.

Most of the liquor distilled at the temperature given above, but a reddish oil was obtained at a temperature of two hundred degrees Centigrade. A thick, vaseline-like substance was obtained at two hundred and fifty degrees Centigrade. The quantity of the latter two distillates was very small—about ten cubic centimeters per liter of gas liquor.

The dry residue was black in color and had the odor of charred bones. It seemed to be the greater part of what has been called "tar" on the preceding page.

Chemical Properties of the Distillate which Distilled Between 0 and 100° C.

1. The liquid is alkaline to litmus.
2. It is quite volatile.
3. It has a very disagreeable odor.
4. It is mobile and miscible with water in all proportions.
5. It has a specific gravity of 1.005.
6. It is soluble in the following reagents; Methyl alcohol, Ethyl alcohol, Acetone, Chloroform, Mineral Acids, etc.

Constituents

The liquor found in the hydraulic main has for its principal constituents the pyridine bases, such as nicotine, picoline, etc. Judging from the odor, the nicotine is in excess of the others. A test with Nessler's solution showed a small per cent of ammonia to be present.

Yield

The yield was found to be about 40 per cent, or about 800 pounds per ton of peat.

Conclusions

Gas made by destructive distillation of peat could be made a fairly good commercial article if the carbon dioxide were removed. Since this objectionable constituent occurs in such large quantities, it could not be economically removed by means of the ordinary purifiers used in coal gas manufacture. Some special method for the removal of carbon dioxide would have to be devised, possibly some method of retorting in which the carbon dioxide was broken up into carbon monoxide and oxygen. With the carbon dioxide removed, the quality of the gas would be considerably improved and by carburetting it could be further enriched.

These experiments are by no means complete nor conclusive and further work is required to determine whether the large amount of carbon dioxide is an unavoidable product of distillation, or whether it is caused by combustion in the retort, or by other causes.

THE FACTORY OF THE LAMARTINE PEAT, LIGHT AND POWER COMPANY (EXTERIOR VIEW) FOND DU LAC, WISCONSIN

The roadway, passing the plant, leads to Fond du Lac, 7 miles due east. The left half of the building is covered over, but the sides are open. It is used for the storage of the wooden pallets carrying the machined peat blocks. It is a storage section for the air drying of the peat after it has been machined.

The right half of the building is enclosed and houses the machinery for carrying on the manufacturing operations. An inclined, tracked runway, for elevatingt he cars loaded with raw peat as they come from the marsh, is seen at the right of the building. In the rear of this runway are seen some of the storage sheds for finished peat blocks while drying.

THE FACTORY OF THE LAMARTINE PEAT, LIGHT AND POWER COMPANY (INTERIOR VIEW), FOND DU LAC, WISCONSIN

The interior of the storage section of the factory is shown here. A very large number of pallets were stored in the building at the time the picture was taken.

CHAPTER XI

THE MANUFACTURE OF WISCONSIN PEAT INTO FUEL

The Lamartine Peat, Light & Power Co., Fond du Lac

The peat marsh and factory of The Lamartine Peat, Light & Power Co., are located about seven miles due west of Fond du Lac. This company, composed of local business and professional men, has been in existence for a number of years. Considerable capital has been invested in the land and factory and operations were carried on for a time. But at present the plant is not being operated. The owners contemplate remodeling the factory with a view of resuming operations on more advanced lines as soon as necessary funds can be secured.

For a general plan of the property see Fig. 17. The factory lies about 800 feet from the eastern edge of the marsh and stands upon a high piece of ground. A system of narrow gauge railway tracks, with turnouts, switches, etc., connects the marsh and factory. Owing to the fact that there is no steam railroad connection, the property is somewhat inaccessible. Material brought to or taken from the plant must be hauled by team over the main road passing the property on the north and leading to Fond du Lac, seven miles due east.

More detailed descriptions of the more important features of the property are given elsewhere.

The Marsh

The marsh from which the peat is obtained covers an area of about 800 acres. It is of the shallow depression type, having good thoroughly decomposed peat to a depth of 7 feet. Roughly, therefore, this deposit has available peat amounting to 1,120,000 tons of finished peat fuel. The peat found here contains decomposed fibrous remains of marsh plants and seeds of aquatic plants. Sedges, grasses, rushes, arrow leaf and ferns make up the principal vegetation growing upon the deposit. Near the center of the marsh are patches of underbrush and bushes, but otherwise it is a characteristic meadow marsh, there being no large vegetation. The peat is

capable of being easily removed for there are no trees, stumps or roots to interfere with dredging or digging operations.

For a general view of the marsh see Plate XVIII.

Quality of the Peat

Sample 303 B given in Chapter VI shows the quality of the peat in this marsh. The analysis is reproduced here. It should be stated that the sample was collected from the marsh, the moisture partly removed before analysis, and then sent to the laboratory. It was not machined in any way.

PROXIMATE ANALYSIS OF PEAT FROM FOND DU LAC MARSH

	Air Dried	As Received	Dry Fuel
Moisture, per cent	11.99	76.94	......
Volatile Matter, per cent	51.03	13.37	57.98
Fixed Carbon, per cent	21.75	5.70	24.72
Ash, per cent	15.23	3.99	17.30
B. T. U., per pound	7,169	1,879	8,149
Sulphur	0.66	0.17	0.74

Air drying loss: 73.80 per cent.

An ultimate analysis of this sample shows it to be made up thus:

ULTIMATE ANALYSIS OF PEAT FROM FOND DU LAC MARSH

	Air Dried	As Received	Dry Fuel
Carbon, per cent	41.50	10.87	47.14
Hydrogen, per cent	5.22	9.57	4.42
Oxygen, per cent	34.81	74.72	27.45
Nitrogen, per cent	2.58	0.68	2.95
Sulphur, per cent	0.66	0.17	0.74
Ash, per cent	15.23	3.99	17.30

The raw peat taken directly from the marsh and analysed in its original raw condition showed a moisture content of 86.16 per cent. After drying in the air of the laboratory for some time it still retained 7.72 per cent moisture.

Some of the machined peat, after having lain in the bins of the plant for several years, analysed as follows:

PROXIMATE ANALYSIS OF FOND DU LAC PEAT

	Air Dried	As Received	Dry Fuel
Moisture, per cent	9.95	15.89	....
Volatile Matter, per cent	48.11	44.96	53.45
Fixed Carbon, per cent	25.14	23.49	27.93
Ash, per cent	16.77	15.66	18.62
B. T. U., per pound	7,468	6,975	8,293
Sulphur, per cent	0.79	0.74	0.88

Methods and Machinery Used in Working the Marsh

An approximate idea of the general layout of the plant and marsh may be had from Fig. 17.

The marsh lies west of the factory. A main ditch, 35 feet wide and 600 feet long, and a branch ditch of the same width and leading from

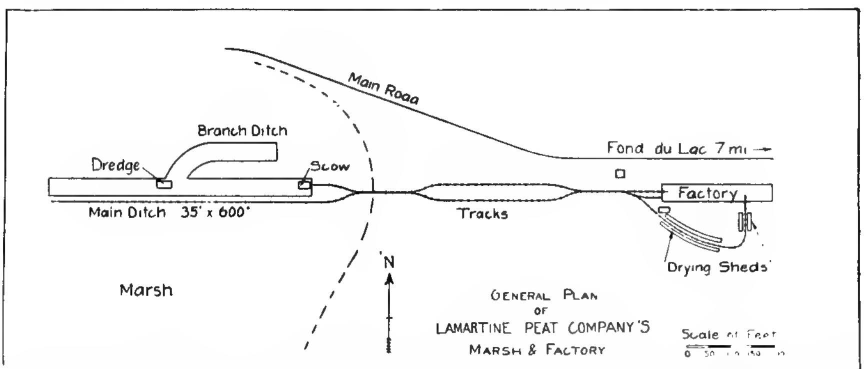


FIG. 17. GENERAL PLAN OF THE LAMARTINE PEAT, LIGHT AND POWER COMPANY'S MARSH AND FACTORY, FOND DU LAC, WISCONSIN

the main ditch as shown, have been dredged out. Raw peat was dug from these ditches by means of a home-made dredge, a photograph of which is shown in Plate XVIII.

The dredge is made up of several parts as follows:

A box-shaped combination knife and scoop, whose dimensions are about 1′ x 3′ x 6′, is mounted vertically as shown and is connected,

by means of wire ropes, to a windlass or winding drum. The winding drum is geared to a two cylinder, reversible Crane steam engine which is supplied with steam by a vertical tubular boiler. This train of apparatus is mounted upon a 15′ x 30′ floating barge so that the scoop can be swung to either side of the barge and over to the banks of the ditch. Also, mounted upon the barge, there is a fuel shed for storing the dried peat which is used for fuel in the boiler. This peat was obtained from the marsh.

In operation, the scoop was forced straight down into the bog about 6 feet, a slab of peat 1′ x 3′ x 6′ in dimensions being cut out in this manner. The loaded scoop, next being raised, was then swung into the desired position, a trip device released, and the load deposited. A flat-bottomed, wooden scow, (see Plate XVIII) approximately 3′ deep, 8′ wide and 50′ long, was brought alongside of the dredge to receive the dug peat. When loaded, the scow was moved to the loading dock at the factory end of the ditch. Here the peat was removed from the scow and loaded upon small cars which were then hauled to the factory over a system of narrow gauge tracks. A track also passes along the south side of the main ditch. It was therefore possible to load the cars directly from the dredge and avoid the rehandling of material. This track was also used to bring supplies and machined peat from the factory to the dredge.

The Factory

As already mentioned, the factory and drying sheds are located on a high point of land about 800 feet east of the marsh. The general features of the factory may be seen from Plate XVII and Fig. 18 prepared from photographs and approximate data taken in the course of field investigations.

Main Building. The main building lies parallel to the road. Its dimensions are approximately; length, 250 feet width; 35 feet; height in front, 38 feet to tip; height in rear, 30 feet to tip. The western section of the building (about 65 feet in length) is a four-story enclosed structure, containing living rooms for the men employed at the plant and also containing the necessary machinery for manufacturing peat blocks. The eastern section (about 185 feet long) is a three-story open, though roofed, structure, used for the storage of the moist machined blocks while drying, and for the storage of the blocks when ready for market. The lower floor

MARSH OF THE LAMARTINE PEAT, LIGHT AND POWER CO., FOND DU LAC, WISCONSIN

This picture shows peat dredge, ditch, rail tracks (partially obscured by grass) to the right of ditch, and factory in the right background.

MARSH OF THE LAMARTINE PEAT, LIGHT AND POWER CO., FOND DU LAC, WISCONSIN

The characteristic meadow type of marsh, with its flat basin, the absence of trees or tall vegetation, and the abundance of grass and sedge, are plainly shown here. Note the dredge in the distance, the ditch ,the scow and track terminals in the foreground. A narrow gauge railroad track runs along the left side of the ditch to and beyond the dredge.

of the western section of the building is built upon the ground level and has masonry walls extending up about 10 feet. Above this is a framed super-structure consisting of three floors. The eastern section is entirely of wooden construction. Four rows of 30-foot telephone poles, extending the entire length of the building, support

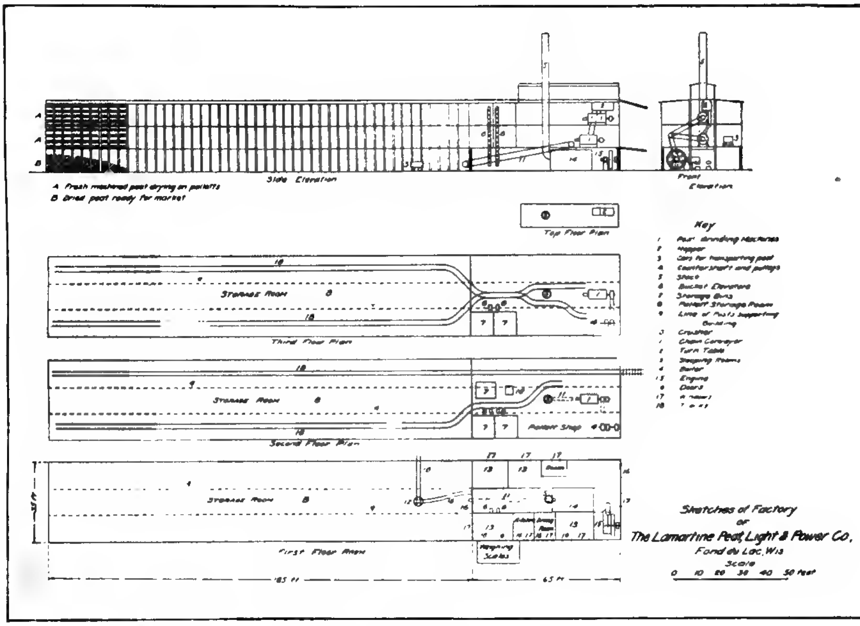


FIG. 18. FACTORY OF THE LAMARTINE PEAT, LIGHT AND POWER CO., FOND DU LAC, WISCONSIN

the floor and roof timbers of the eastern section. The poles in each row are approximately four feet apart and the rows of poles are about 12 feet apart.

A kitchen, a dining room, and several sleeping rooms for accommodating the employees, are found in the lower or first floor of the western section of the building. Here, also, are located the boiler and engine used to drive the peat machinery. In the second and third stories are the peat cutting and moulding machines and necessary countershafting and pulleys. Here also, are several storage bins. A hopper, for the reception of the raw peat received from the marsh is located on the fourth floor. Cars, tracks, bucket elevators and a chain conveyor, shown in the diagram, are employed for transporting the peat material from point to point. A peat crusher is located on the second floor.

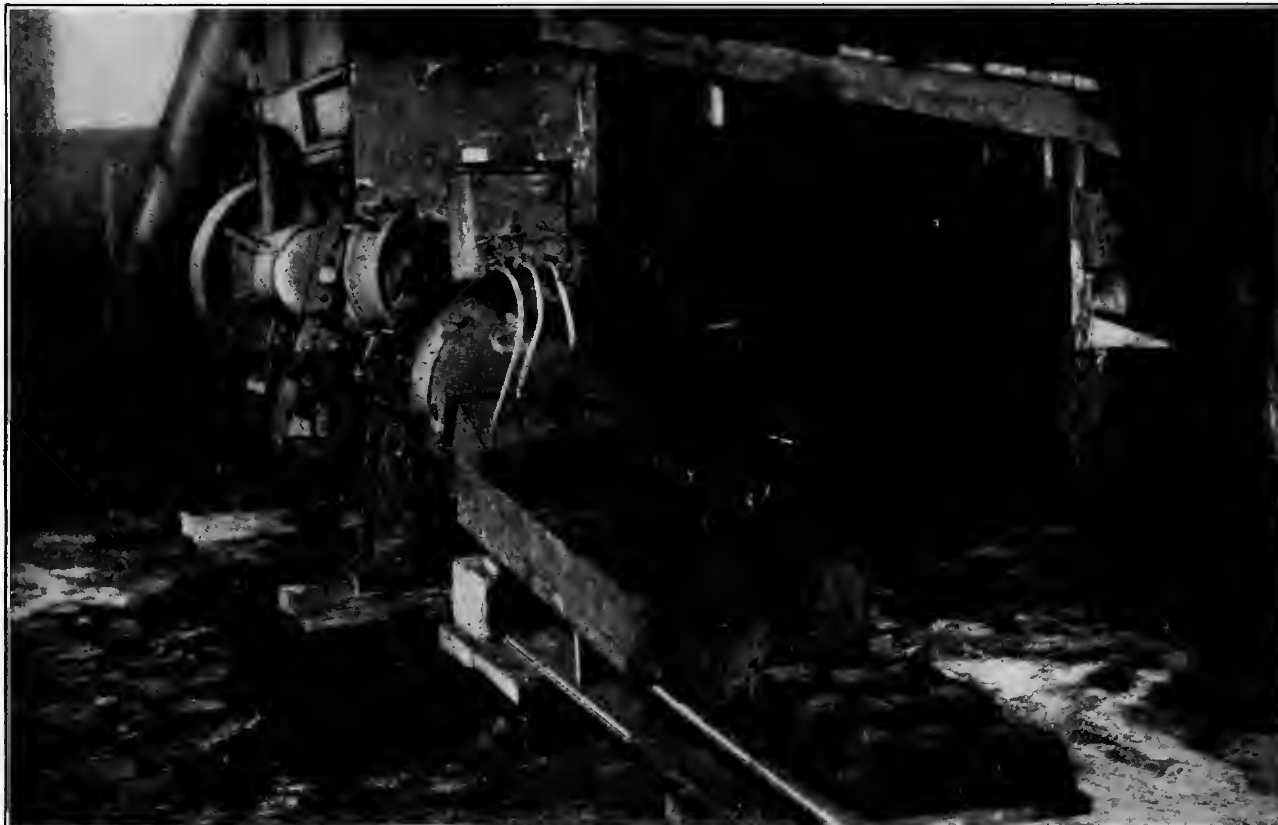
The two upper floors of the eastern section of the building are used for the storage of machined peat as it comes from the presses. After the peat has been dried and is ready for market, it is stored on the ground floor of this section.

Drying Sheds. Immediately south of the factory are five open, roofed sheds in which the peat, after having been formed into blocks and machined, is stored for air-drying. These sheds are about 10 feet high, 12 feet wide, and of different lengths, one shed being about 10 feet long, two about 120 feet long, and two about 160 feet long.

Method of Operating Plant

Operation of the plant was carried out on the following lines. Peat, dug by the dredge, was dumped either into cars directly or first into the scow and then into the cars. Next, over tracks provided for that purpose, the loaded cars were moved up the hill and to the top story of the factory. Here the material was dumped into a hopper. A screw, operating inside of the hopper, fed the raw peat through rectangular chutes into the pug mills which thoroughly cut, ground and mixed it. There were two of these machines, one on the third and one on the second floor, connected to the hopper by the chutes in such a way that the peat material could be guided into either one or both of the mills. These pug-mills had moulding attachments, consequently, the material left the machines in the form of rectangular bricks about 3″ x 4″ x 8″ in size. It was not possible to obtain a satisfactory picture of these machines but they are similar to the one shown in Plate XIX. This plate was reproduced from Bulletin 376 of the U. S. Geological Survey and gives a good idea of the Fond du Lac machines as well as of the peat blocks which the machines turned out.

Bricks manufactured on the third floor were then placed on crate-like, wooden holders called palletts, loaded on cars, and stored in the third floor section devoted to air drying. Some of the blocks issuing from the pug mill on the second floor were handled similarly, having been stored in the second floor drying section. Another portion of this material was placed on palletts and carried to the ground floor by the chain conveyor. When the blocks arrived at the lower end of the conveyor, they were loaded on cars and taken to the sheds, south of the plant, and allowed to air dry for a time. Finished material was stored in piles on the ground floor of the eastern section until required for delivery to consumers.



PEAT PRESS FOR MAKING 50 TONS OF MACHINE PEAT A DAY

In operation at the Fuel-Testing Plant of the U. S. Geological Survey, Jamestown Exposition, Norfolk, Va., October, 1907
From U. S. Geological Survey.

Some of the dried blocks were run through a crusher and the crushed peat, so obtained, was carried by bucket elevators to bins.

All of the machinery was driven by a steam engine which took its steam from a boiler. Both boiler and engine were located in the lower floor. Water for the boiler was drawn from a well underneath the factory. Peat was used for fuel in the boiler.

Miscellaneous

Dr. C. A. Beebe of Fond du Lac, the chief promotor of this enterprise, supplied the following information.

Capacity of Plant. One hundred and sixty tons raw material in ten hours. The method of digging was not satisfactory. For lack of money, a first class dredge could not be provided, and the makeshift that was used could not get peat out fast enough to supply the capacity of the plant.

Kind of machines. One machine was built after the design of Dr. Beebe and had a capacity of ten tons per hour. The other, operated in connection with a clay pug-mill, was a stiff mud brick machine with modified screw and die. It had a capacity of about six tons per hour.

Size and Kind of Engine. One hundred and twenty-five H. P. Reynolds Corliss. Engine was loaded up to about 60 H. P.

Number of Men Employed. Sixteen to eighteen. At times, less.

Cost of Plant and Accessories. Approximately $26,000.

Cost of Manufacture. This must be estimated, as more or less construction work was going on at the same time that plant was in operation. With a good dredge to supply the plant with raw material, it is estimated that the labor cost could be kept below $1.00 per ton.

Selling Price. Air-dried peat sold for $6.00 per ton in Fond du Lac. However, it is thought that this price is too high to make a market for a large output.

Peat fuel was made and sold at Fond du Lac during the summers of 1905 and 1906. But since that time the plant has not been operated. Experiments have been carried on, however, with a view of utilizing the peat in this deposit for paper making, in gas producers, and in various distilling carbonizing and chemical processes for the recovery of by-products from the peat.

Concerning the use of the peat for fuel, Dr. Beebe has to say, "Our peat fuel gave the best satisfaction in cook stoves and grates. We have many testimonials certifying that people preferred peat to any other fuel they ever used. I burned it one winter in my furnace at home with good results. We used it continuously under our boiler at the plant. Dry peat raised steam quicker than any other fuel we tried. The boiler was always clean. At long intervals the form of cleaning was carried out, but it was wholly unnecessary. The greatest criticism of peat fuel is that it burns up quickly. It contains so much oxygen that little draft is required. Consequently, experience and judgment are necessary to get the best results."

Two economic features—or rather defects—of this plant are brought to mind.

1. The plant was located about $\frac{1}{8}$ mile from the marsh. Consequently all the water in the raw peat had to be hauled this distance and a waste of energy was thereby involved. The expense of handling raw material would have been much less had the plant been located nearer the marsh.

2. The plant was several miles from a railroad track and, assuming that the peat could have been manufactured economically, there was too much expense connected in hauling the finished product from factory to nearest railroad line or possible markets.

Gas From Fond du Lac Peat. The experiments described in Chapter X were made upon peat from the Fond du Lac plant. By referring to that chapter additional information concerning value of this deposit for gas making purposes may be obtained.

The Whitewater Peat Company—Whitewater

Lying about $1\frac{1}{4}$ miles west of the city of Whitewater, is the marsh of the Whitewater Peat Company. Located at the edge of the marsh was the company's peat briquetting factory.

This company seems to have been the outgrowth of certain experiments carried on by Lieut. J. O. Green and was formed to manufacture peat with machines invented and patented by J. O. Green and H. T. Martin, of Whitewater. In 1898, the peat located at this deposit was studied by Green for the purpose of determining the value of some of the by-products derived from it. In 1899, Messrs. H. T. Martin and J. O. Green built a peat compressor of their own design which turned out a product having the appearance of gutta-percha. Following this, three patents were taken out. Two of these were on the compressing machine and one covered "the process for compressing peat fuel by hammering the dry, ground, product through a tube or die with sufficient rapidity to release the tar therein contained for the purpose of binding the same together." Local capital supplied the funds for the formation of a company for manufacturing peat fuel by these machines and processes.

Peat was manufactured at this plant in 1902, but at present the plant is completely dismantled and the building is used to store hay cut from the marsh.

The factory was located immediately adjoining the marsh and stood upon a slight rise of land to the east of the marsh. Two main ditches were worked and there was at one time a system of narrow gauge tracks and cars for transporting the peat from the diches to the factory. There was no steam railroad connection with the property, but a wagon road, crossing the marsh, leads to Whitewater, $1\frac{1}{4}$ miles distant.

The Marsh

Lying west of the factory is the marsh from which the peat used in this plant was obtained. The marsh is of the characteristic shallow-depression, meadow type. Most of the surrounding land is hilly, and under cultivation. Covering 640 acres and being 9 feet in depth, this deposit contains excellent, thoroughly-decomposed peat capable of yielding 1,152,000 tons of finished peat fuel. The

vegetation is principally grassy and sedgy, with some moss growths. Since there are no trees, stumps, or large roots to interfere, the peat is easy to dig. Plate XX shows two views of the marsh.

Quality of the Peat

Three samples of the raw peat taken from this marsh are given in the following table and have the analyses shown.

PROXIMATE ANALYSIS OF RAW PEAT—WHITEWATER MARSH

		1	2	3
Sample No.		1	2	3
Depth, feet		9	5.5	3
Proximate Analysis	As Received—Moisture, per cent	69.4	85.5	82.8
	Dry Fuel			
	Volatile Matter, per cent	38.4	60.4	58.2
	Fixed Carbon, per cent	16.9	27.8	26.6
	Ash, per cent	44.7	11.8	15.2
	B. T. U., per pound	6,040	9,440	9,040
	Combustible			
	Volatile Matter, per cent	69.5	68.5	68.7
	Fixed Carbon, per cent	30.6	31.6	31.4
	B. T. U., per pound	10,900	10,700	10,650

Remarks:—Location of all samples, 300 ft. west of factory. Sample 1 was taken too near the bottom of the deposit and contained some clay and sand.

THE WHITEWATER PEAT COMPANY'S MARSH, WHITEWATER, WISCONSIN

The marsh is shown in the background. Running from left to right in the center of the picture is seen the old ditch from which peat was dug. In the right corner are two drying sheds. In the foreground are seen the remains of wrecked cars used for transporting the raw peat from the ditch to the factory.

THE WHITEWATER PEAT COMPANY'S MARSH, WHITEWATER, WISCONSIN

A nearer view of the air-drying sheds and the ditch with its exposed peat surfaces. The ditch swings to the right in the right background. A wrecked peat car lies in the ditch.

That the changes which the peat undergoes as a result of working may be noted, the following table is given:

PROXIMATE ANALYSIS OF WORKED PEAT—WHITEWATER MARSH

Sample No.		4	5
Depth, feet		6–8	6–8
Proximate Analysis	As Received—Moisture, per cent	33.4	14.0
	Dry Fuel		
	Volatile Matter, per cent	57.4	59.7
	Fixed Carbon, per cent	25.4	29.4
	Ash, per cent	17.2	10.9
	B. T. U., per pound	9,370	8,600
	Combustible		
	Volatile Matter, per cent	69.4	67.0
	Fixed Carbon, per cent	30.7	33.0
	B. T. U., per pound	11,300	9,695

Remarks:—Both samples originally came from the ditch.

Sample 4 was taken from some of the unground and artificially dried, but not compressed, product at the factory. It had been standing for some months.

Sample 5 was taken from some of the compressed commercial product made in 1902 at the Whitewater factory. Said to have been stored in a rather damp place.

The Factory

The factory consisted of a single frame building about 35 feet wide, 50 feet long and 35 feet high. Its general appearance is best seen in Plate XXI. This building housed a boiler and engine used to drive the machinery, necessary line shafting, pulleys, etc., a peat grinder and the peat briquetting presses. Later a steam drier and evaporator were added to the original equipment. Added to the front of the building were two 12′ x 20′ bins for the storage of the finished briquettes. The floors of these bins were sufficiently high to permit wagons to be driven under them. Spouts or chutes led from the bottom of the bins. Below the bins and on the ground were platform weighing scales Thus it was possible and

convenient for wagons to be loaded while standing directly below the bins and, while standing on the scales, to be weighed at the same time.

Methods and Machinery Used in Working the Deposit

An extremely simple system was employed in operating this property. It was essentially as follows:

First, the peat in the bog was cut into blocks by slaynes or peat spades which cut out blocks of peat 8″ x 6″ x 3″ in size. These were then piled up to dry in small air drying sheds located on the marsh. Two sheds are shown in the pictures. (See Plate XX). Underneath the sheds the surface of the ground was covered with boards, and the peat, lying upon these, was prevented from absorbing moisture from the ground. Being roofed, the sheds protected the stored peat from the rain. The sides of the sheds were open and permitted free access of air to the peat. From four to five weeks were required to dry the peat in this manner. And at the end of this time the moisture content became reduced from 90 per cent to 20 per cent.

Next, the air-dried peat was transported from the drying sheds on the marsh to the factory by means of small cars and tracks. At the factory the blocks were broken up and ground in an ordinary corn grinder so that peat having the consistency of cornmeal issued from the grinder.

Following the drying and grinding processes, the peat was fed directly into the briquetting machines. (See Plate XXII). Here it was formed into circular disk-like briquettes, two inches in diameter and three-eighths of an inch thick. In the process of forming these briquettes they became coated with a tarry covering which gave them a dark, shiny, smooth, coal-like appearance.

Finally, the briquetted peat was elevated and stored in bins already described, until required for consumption.

Mr. J. O. Green stated that the cost of manufacturing these briquettes was about $2.00 per ton.

Operations were continued for some time along the lines above outlined. And the results were apparently successful. But the necessity of waiting five weeks for the natural air-drying process to be completed led to experiments along the line of artificial drying. Accordingly, a peat drier, costing from $2,000 to $3,500, and guaranteed to handle peat containing 50 per cent of water, was purchased. As the peat was dug from the marsh it was hauled to the factory

FACTORY OF THE WHITEWATER PEAT COMPANY, WHITEWATER, WISCONSIN

The factory is located at the edge of the marsh on a piece of ground somewhat higher than marsh level. After the raw peat was briquetted the briquettes were stored in the bin or hopper shown at the right end of the factory. The ditch from which the raw material was obtained is shown in the foreground.

in its moist condition and passed directly into the drier, then, when dry, into the presses. Uneconomical operation and failure of the company resulted.

Briquetting Machines

Plate XXII gives a general idea of the peat briquetting machines used in this factory. They were made by Green, Martin and Ward, of Whitewater, Wisconsin, and are of a type resembling those machines which produce "seared briquettes."

A crank or cam shaft, having a pulley at one end and a fly-wheel at the other, and having a speed of from 1,000 to 1,800 revolutions per minute, operated two pistons or plungers having diameters of about 2 inches and strokes of about 2 inches. Each one of two tubes, open at both ends, had one of the pistons fitting into its upper end, while the lower end of the tube was open and had the cross section of the finished briquette. The pistons and tubes were arranged in pairs so that the motion of the presses might be more uniform and their operation more continuous. But, since both sets of tubes and pistons were alike, only one set will be described.

The bore of the tube was tapering, so that its lower end had a slightly smaller diameter than the upper end. In operation, the ground peat was fed into the upper end of the tube, the piston descended and compressed the charge into a briquette, the piston rose and more material was fed into the tube between the piston and the briquette previously formed, the piston then descended and formed a new briquette and, at the same time, forced the first finished one out of the lower, open end of the tube. Thus, for each forward stroke of the piston, one flat, hard, compact, circular briquette was made. The resistance of the material passing through the taper tube caused sufficient friction on the sides thereof to make compact briquettes in this manner. As a result of the 1,800 or more blows struck by the plungers per minute, together with the heat generated by the friction of the material rubbing against the sides of the tubes, enough energy was set free to liberate some of the tarry matters contained in the peat. This tar bound the particles of peat together and formed an impervious coating over the surface of the briquette, thus preventing the absorption of moisture by the briquette. In addition, there was also a steam heating jacket which surrounded the lower ends of the tubes to assist in setting free the tarry matters.

While, by this process, one briquette was formed by every blow, the material issued from the machine in one continuous plug having lines of cleavage representing the briquette surfaces. (See Plate XXII). Because of these lines of cleavage, the plug was capable of being broken off at any desired length. A plug 9 feet long has been produced by the Whitewater machines.

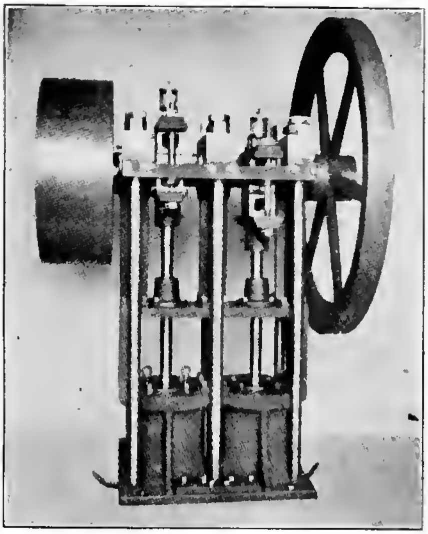
These presses were guaranteed by their makers to have a capacity of one ton of briquettes per hour. It is reported that one of these presses, used at Bancroft, Mich., turned out 2.4 tons per hour. Cost of machine, $1,500. Weight of machine, 2½ tons.

Tomah Experiments

A machine of the kind used at Whitewater was used by Earl Niecke at Tomah, Wisconsin. The briquettes made at Tomah are slightly larger than the Whitewater briquettes. And, on account of the fact that the peat at Tomah has a more fibrous texture than that at Whitewater, the briquettes are also more fibrous.

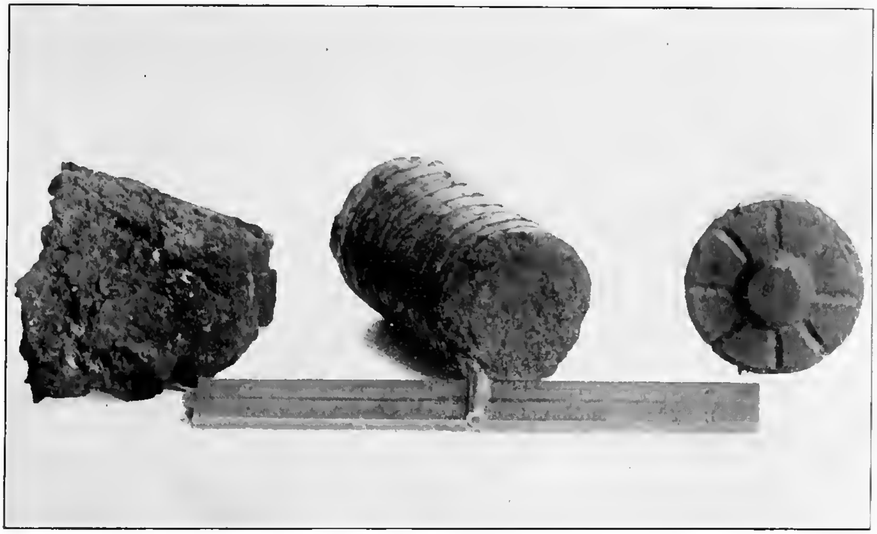
The Tomah plant was a rather small plant and is not being operated at present.

In 1905, the Geo. Heilman Brewing Co. of La Crosse tried out two or three carloads of peat briquettes which were made by the Tomah machines, the peat coming from an extensive bed near there. The briquettes were of a brown color, measuring about four inches long by three wide, similar in shape to a cake of toilet soap, being rather hard, but not as hard as coal briquettes. They were fired under a steam boiler and, while they made a hot fire, they burned so quickly that it was found impractical and not economical to use them. They were practically smokeless, but left a considerable quantity of ash. They were also tried out in a cook stove and, while they were nice to handle, were not considered as a success.



BRIQUETTE MACHINE OF THE WHITEWATER PEAT COMPANY, WHITEWATER, WISCONSIN

This new model peat machine was used for making peat briquettes at Whitewater. It was manufactured by Green, Martin and Ward of that city. Weight, $2\frac{1}{2}$ tons; capacity, 1 ton per hour, cost, about $1,500.



RAW AND BRIQUETTED PEAT FROM WHITEWATER, WISCONSIN

The chunk on the left is a block of air-dried peat as dug from the marsh. When dried, ground, and run through the briquetting machines it issues from them in plugs like those in the center of the picture. These plugs have been obtained from these machines nine feet in length. The plugs are made up of a number of disk-shaped briquettes, one of which is shown to the right. The circumferencial lines on the plug are lines of cleavage representing the flat surfaces of successive briquettes. By comparison with the rule in the foreground the relative sizes of the different specimens may be noted.

CHAPTER XII

MISCELLANEOUS ATTEMPTS TO UTILIZE WISCONSIN PEAT

Peat Paper

Certain experiments have been carried out along the line of manufacturing Wisconsin peat into paper and it has been demonstrated that an excellent product suitable for the manufacture of box-board and packing cases, can be turned out.

It was discovered that the top $3\frac{1}{2}$ feet of the Fond du Lac bog could be made into box-board and for a time there was a possibility that a mill for the manufacture of peat paper board might be erected near this deposit. During the summer of 1907, experiments were made along these lines. Several car loads of raw peat were taken to Beloit, Wisconsin, and made into paper board over an ordinary straw-board mill. From 20 per cent to 50 per cent of old paper was added to the peat material and an excellent product resulted. No figures are available, however, covering the economics of the manufacturing operations in these particular experiments.

About 1907, a Chicago paper company took an option on the Fond du Lac property. This company failed, its failure being attributed to the financial panic of 1907.

Cranberry Culture*

Wisconsin affords rare natural resources for a cranberry industry. During the last decade, 12 per cent of the cranberry crop of the United States was produced upon Wisconsin marshes. Wisconsin cranberry growers have in their possession 50,000 acres of marsh land, of which 5 per cent, or 2,500 acres are planted. At least 20,000 acres are available. Of the 2,500,000 acres of marsh land, several thousand are available in the northern lake region for cranberry culture. The majority of the cranberry crop of Wisconsin is grown

*Digest from the following pamphlets:

Malde, O. G., "Cranberry Bog Construction for Wisconsin." Bull. 213, University of Wisconsin Agricultural Exp. Station, 1911.

Malde, O. G., "Cranberry Bog Management for Wisconsin." Bull. 219, University of Wisconsin Agricultural Exp. Station, 1912

in Wood, Jackson, Monroe, Juneau, Winnebago, Waupaca, Waushara and Barron counties. Other bogs are found in Burnett, Washburn, Marinette, Shawano and Marquette counties. Figure 19 shows the cranberry growing sections on the map. The counties of

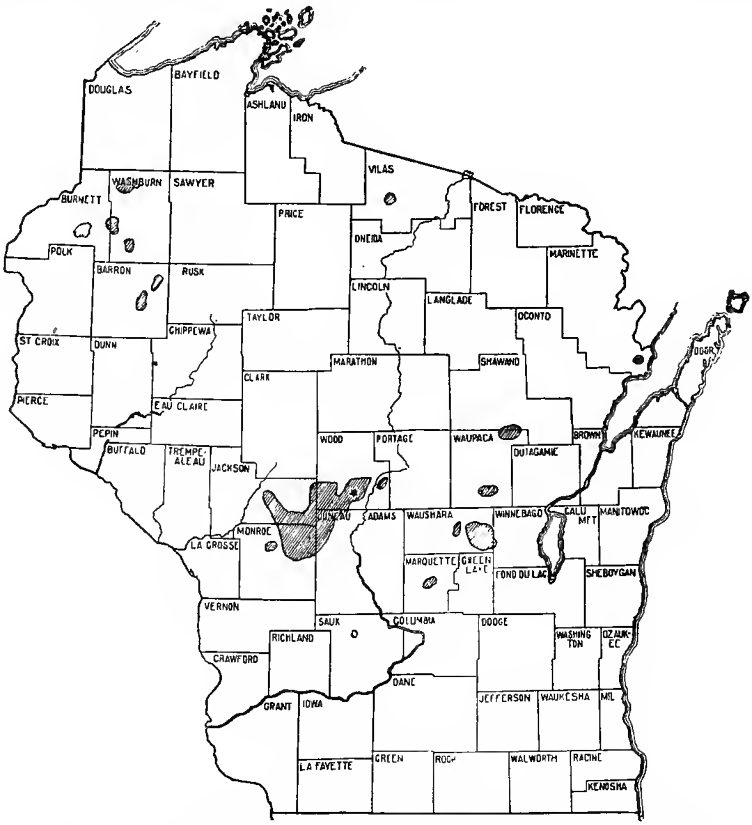


FIG. 19. CRANBERRY-GROWING DISTRICTS OF WISCONSIN

Map furnished by the College of Agriculture. Wisconsin produced over 50,000 barrels of cranberries in 1912.

the lake region of northern Wisconsin, including Douglas, Bayfield, Ashland, Vilas, Forest, Oconto, Shawano, Langlade, Lincoln, Oneida, Price, Sawyer, Rusk and Taylor, contain numerous suitable locations. The southeastern portion of the state contains a few suitable locations, in Columbia, Jefferson and Waukesha counties in particular, but that portion of the state being in the limestone district, or bordering on it, makes it in most cases less desirable, as the acid soils are essential to the production of cranberries.

Development of Peat Soil for Crops

In a number of instances peat marshes have been drained and the waste land made suitable for the raising of crops. Of the agricultural value of muck and peat, E. R. Jones writes as follows:*

"That peat and muck marshes can be drained and made valuable agricultural land is firmly established. On a bed of peat from four to ten feet deep, M. J. Vea, at Stoughton has raised three successive crops of corn, the yield in 1911 being over 80 bushels per acre on 33 acres. About one half of this was sold as seed corn for more than two dollars a bushel. Carl Foll, at Deerfield, reports yields almost as good as this for a period of years on about 80 acres of the same kind of land. Both of these areas were tiled with lines laid from 3 to 4 feet deep, from 66 to 100 feet apart and costing about 25 dollars an acre. Previous to drainage these areas were too soft and wet for satisfactory pasture, and too boggy to admit of cutting the poor quality of grass for hay. Formerly these lands found no buyers at ten dollars an acre. Today in these localities undeveloped marsh lands are bringing from 30 to 60 dollars an acre and Messrs. Vea and Foll would not sell their drained peat lands for 100 dollars an acre. With drainage the reddish peat had become a solid, well-decomposed black muck. Immediately after drainage, all adjacent fires were guarded to prevent the possible burning of the peat. The muck of today is less subject to damage by fire, and a great deal of it has become so solid that it will not burn at all."

Miscellaneous Attempts at Peat Utilization

It has been reported that some experimental work is being done by Milwaukee parties along the lines of developing producer gas from peat. But communications addressed to these parties brought replies revealing the fact that "nothing has been sufficiently developed to be of interest to the Wisconsin Geological and Natural History Survey."

Dr. C. A. Beebe reports that a short time ago an experimental plant was operated in Milwaukee under the control of an experienced chemical engineer. Fond du Lac peat was experimented upon and results obtained seemed to show that this peat, containing as much as 70 per cent moisture, could be used in a gas producer so as to generate a good gas. It was also apparently shown that a large

*Jones, E. R., Third Biennial Report of Wisconsin Conservation Commission, 1912, p. 61.

percentage of sulphate of ammonia could be recovered from the Fond du Lac peat. Details of the experiments are not available at the present time.

A company operating iron furnaces at Mayville, has recently experimented upon the peat in the Horicon marsh with a view to utilizing it in some of the processes incident to the manufacture of iron. Results of these experiments are not available.

In speaking of the people and conditions of the northeast corner of Monroe county, the Rev. Urban Gibson is reported to have said as follows:

> " 'Mossing' is their 'easy money' occupation and many of them refuse to do much else. The marshes are filled with heavy moss, the kind nurserymen use to pack around the roots of trees and shrubs when they are shipped. These people go into the marshes when they are wet, rake the moss into little piles like muskrat nests and wait for freezing weather.
>
> "Then they take a team and an ax, chop out the frozen heaps of moss and haul them to high ground. When the warm weather comes, the moss dries, and is put in bales averaging about fifty pounds, for which they get from 35 to 50 cents a bale. I know of one man who made $500 in a season."*

*Chicago Record-Herald. Feb. 1, 1914. Milwaukee Correspondence.

PART IV

THE POSSIBILITIES OF A PEAT INDUSTRY IN WISCONSIN

Introduction

A review of the material presented in the foregoing chapters of this report and a study of the literature on peat will show what peat is, how it may be used, and that peat and its by-products in certain forms possess properties of some value. That it may be used as a fuel and as a raw material for other than fuel purposes is proven by the fact that it is so used in Europe.

Reports show that in 1902 Russia produced 4,000,000 tons. Holland produces 1,000,000 tons per year. In 1909, Sweden produced 64,000 tons of fuel, 1,655,635 bales of peat litter and 1,167,525 cubic meters of loose peat. Denmark produced 89,000 tons in 1909 and 82,000 tons in 1910. France and Germany produce some peat. Large quantities are consumed annually in Ireland. In general, it is estimated that 10,000,000 tons are consumed in Europe yearly, and that the consumption is increasing.

In Canada considerable experimental work has been done by the Government. The scarcity of Canadian coal fields and the long winters of the Dominion have been incentives to experimentation along the line of utilization of the extensive peat deposits of that country. Some peat fuel has been produced and sold in the provinces of Ontario and Quebec for a long period, but no conspicuous success has become evident.

In the United States, little progress can be reported. Small quantities of cut peat were used in New England in the early days of the American nation, before the universal use of coal. During the Civil War some peat was manufactured and used, but this use did not continue for long. Again, the anthracite coal strike and consequent coal famine of 1903 caused a resumption of activity along the lines of utilization of peat deposits. But after the settlement of the strike, peat development again became dormant. The U. S. Census of 1910 showed that the total number of peat enterprises in the United States in 1909 was 12, of which 10 were producing and 2 non-producing. These industries were located in Illinois, Indiana, Iowa, Maine, Massachusetts, Michigan, New Jersey, and Pennsylvania. The United States Government has carried on some investigations but these have not led to any important developments.

The peat industry has not reached any satisfactory degree of development in Wisconsin. In fact, there is no peat industry in

Wisconsin and practically no development work is going on. This volume records the principal attempts along the line of peat utilization in this state.

With this information before us, it is quite natural to inquire why peat has never been used to any great extent in America, why the great deposits found in this country cannot be put to use, and whether or not they will ever be of any commercial value. In short, What are the Possibilities of the Development of a Peat Industry in Wisconsin? Light may be shed upon these questions by a study and analysis of some of the commercial factors involved.

CHAPTER XIII

FACTORS INVOLVED IN THE DEVELOPMENT OF A PEAT INDUSTRY IN WISCONSIN

In attempting to forecast the future development of Wisconsin peat deposits, a study of the entire project becomes essential, and a careful, detailed consideration must be given to each factor involved. There are a number of factors governing the commercial development of any peat deposit which have already been briefly pointed out in Chapter II. Careful study and analysis must be made of all of these before engaging in any peat development work. This applies to Wisconsin conditions as well as to conditions elsewhere. There are other factors, relating particularly to Wisconsin, some of which will be pointed out briefly in the present section.

Lack of knowledge concerning some of these matters has in the past resulted in the failure of peat projects in this state and in most instances financial losses have followed because such factors were not understood or taken into account. Indeed, the importance of these factors and their bearing upon the development of Wisconsin peat deposits is not yet well understood.

MOISTURE—THE REAL PROBLEM

The main problem which must be solved before much can be accomplished in the way of peat development and utilization is that of getting rid of the moisture which the raw material contains. As already shown, Wisconsin peat, like all other peat, in its natural state, contains sometimes as much as 95 per cent of water. Such material will not burn until some of the water has been removed. A way must be found to remove it quickly, efficiently and cheaply. As yet no such drying method has been discovered.

Artificial drying by means of the application of external heat has been tried but has failed to work out in practice. Davis * writes as follows:

"The great obstacle to success in these efforts is found in the fact that the real problem, as stated in simplest terms, is how to recover from a mixture of 85 to 90 per cent of water and 10 to 15

*Davis, C. A., "Geol. Survey of Michigan." Annual Report, p. 336.

per cent of peat, this small portion of the latter substance, which, when received in a dry state, and burned, will only give heat enough to dry the water from one-third as much more. It is evident that such a problem is not easily solved if the fuel has to be all dried out by artificial means. It is undoubtedly a vital objection which can be urged against all systems of artificially drying peat, that they use three times as many heat units as the resulting fuel will produce, and therein lies the chief reason why such processes have not, in the long run, proved profitable, even where a large amount of waste fuel, in the form of peat refuse, has been available. The cost of drying, figured in tons of peat, is three tons of dry peat, or its heating equivalent, for every ton of dry peat produced, and after it is dried, to this must be added, to determine the selling price, the cost of digging, taking to the drying machinery, the removal from this to the presses, the operating and maintenance of these, the interest on capital and the charges for storing and selling."

In further explanation of the difficulties encountered in artificial drying is the following:

"The idea of the possibility of drying the wet peat as dug out of the bog, by means of artificial heat alone, seems still to prevail amongst a number of people interested in the peat industry. A very simple calculation shows, however, the impracticability of such an undertaking. Assuming that a drained bog contains $12\frac{1}{2}$ per cent of dry peat substance, which is a good average, 100 pounds of wet peat contains $87\frac{1}{2}$ pounds of water. Assuming further that 80 per cent of the fuel value of the fuel used could be utilized, that 1,100 B. T. U. are required to evaporate 1 pound of water, and that the dry peat has a calorific value of 9,000 B. T. U. per pound; in order to evaporate the water, we consequently require:

$$\frac{87.5 \times 1{,}100}{.80 \times 9{,}000} = 13.3 \text{ pounds of dry peat substance}$$

or more than is contained in the peat." *

The use of fuel for drying is, therefore, a costly, inefficient, and impractical process.

A number of other methods of artificial drying by means of electricity, pressing or squeezing, centrifugal machines, filtering, superheating, waste gases, have been tried for the removal of water. But none of these has proved successful.

*Nystrom, E., and Anrep, S. A., Canadian Dept. of Mines, Bulletin 1, 1909., p. 21

A method of drying, which has met with a fair degree of success in Europe, consists of draining the deposit before attempting to work the peat. When drained, the material is dug from the deposit and laid on the surface to air-dry for a period varying from one to two months. After this air-drying treatment, it is worked into final shape for market. Considerable time is required for drying, but the major part of the water is thus removed naturally by air, sunshine and drainage. Whether or not such treatment is necessary under American conditions is an open question. It would seem, however, that such methods would not be satisfactory in a country where large scale production is necessary to hold down costs. To produce large quantities of peat fuel under conditions found in America, would seem to require some scheme of artificial drying. But, unfortunately, such a process has not yet been perfected.

Until some economical arrangement for drying raw peat is devised, peat will not become an important article of commerce. For it is only after the water has been reduced to at least 25 per cent that peat can be used at all.

In the present state of the art, air drying seems to be the most efficient method yet attempted and artificial drying has proven to be a failure.

Ash

The amount of ash which a fuel contains affects its commercial value. Ash replaces useful, heat-producing substances, and uses up heat when its temperature is raised to and maintained at that of the fire. It acts as a diluent, serves no useful purpose, and makes necessary the handling of a large quantity of material of no fuel value. A fuel is ordinarily considered of poor grade if it contains more than 15 per cent of ash.

In the case of Wisconsin peat, we find that the ash content varies considerably, sometimes being as low as 6 per cent and again running as high as 70 per cent. The average value is in the neighborhood of 20 per cent. Some of the grades containing small amounts of ash might be commercially useful. Peat containing up to 20 per cent of ash might find use for domestic purposes in certain localities in the vicinity of a peat deposit where a better fuel could not be obtained easily and cheaply. For use in the industries, peat containing over 20 per cent ash would probably be considered worthless.

The relation of ash to the fuel value is clearly brought out in Figure 8. Here it will be observed that those samples of peat having the smallest amounts of ash are also those which contain the greatest heating value and also the greatest percentages of fixed carbon and volatile matter. Within certain limits the fuel value of the peat varies in inverse proportion to the amount of ash it contains. Therefore, ash content is a fair index of the quality of the peat. The sources of ash in peat were already explained elsewhere and it is not necessary to go into them here.

The large amount of ash in Wisconsin peat makes it an inferior fuel and is one of the reasons why the peat has little commercial importance at the present time.

Heating Value

The commercial worth of a fuel depends to a large degree upon its heating ability. This factor is an index of the value of the fuel for heating and steam-raising purposes. It is regarded of such importance that fuels which are to be used for such purposes are now largely purchased on a heat-unit basis.

The heating value of Wisconsin peat ranges from about 3,000 B. T. U. to 11,000 B. T. U. The average is about 8,000 British Thermal Units per pound. High ash content accounts for low heating value in Wisconsin peat. The intimate relation that exists between the heating value of peat and its ash content has already been explained. Those samples of peat which have the highest heating value are those which have the lowest ash content.

Some idea of the utility of Wisconsin peat for heating and steam-raising purposes is obtained from this factor. It shows that Wisconsin peat is an inferior fuel, standing between lignite and wood. It is considerably inferior to good coal in this respect, about two tons of peat being equivalent to one ton of coal.

Combustible Matter

The combustible matter in a fuel is the sum of the fixed carbon and volatile matters which it contains. In the presence of the oxygen of the air supply, the combustible burns and produces heat.

Wisconsin peat has a fixed carbon content averaging 24.0 per cent and a volatile matter content averaging 56.4 per cent. The sum of these, 80.4 per cent, gives the combustible contents. These figures are all for dry and moisture-free fuel. In its combustible contents Wisconsin peat ranks favorably with other peat.

These combustible matters, but more particularly the volatile materials, form some sort of an index to the possibility of gasification of peat. The character of these volatile matters is also an index of the by-products which may be obtained from peat and points out the possibility of development of chemical industries using peat as a raw material.

Competition

Peat in Wisconsin has competitors in wood, mineral oil, coal and water-powers. Wood is used as a fuel to a limited extent only, and then chiefly for household purposes. The waste of wood-working plants is sometimes used for steam-raising purposes. For such uses wood is still superior to peat. Our forests are gradually being destroyed, however, and, unless some scheme of reforestation is carried out, wood will probably not much longer continue to be used as a fuel. Mineral oil is used and will probably continue to be used as a fuel to a limited extent in Wisconsin. Natural gas is not found in this state and will probably never become an important factor in the fuel situation in Wisconsin. Coal is by all means the most important competitor of peat at the present time. It is still plentiful, easy to get, and the price is not yet excessive or prohibitive. Many years will elapse before our coal supplies reach this point. Wisconsin's water-powers are a very important factor in the industrial affairs of the state and surely will become more important in the future. Undoubtedly, these water-powers will eventually supply a considerable portion of the total energy required by the industries of the state.

The bearing of coal and waterpowers on the future development of Wisconsin peat deposits will now be discussed briefly.

Coal Supply

The reports of the United States Geological Survey give the following information about coal supplies. *

> The known coal areas of the United States embrace a total area of 310,296 square miles, to which may be added something over 160,000 square miles of which little is known but may contain workable coal, and about 32,000 square miles where the coal lies under heavy cover and is not considered available under present conditions.

*U S. Geological Survey. Report on the Mineral Resources of the U. S., 1912. Part II, p. 28.

The supply of coal before mining began is estimated to have been 3,076,204,000,000 short tons.

The quantity of coal still remaining to be mined is 3,061,000,000,000 tons or a little more than 99.5 per cent of the original supply.

About 2,000,000,000,000 of this is available for fuel or 4,000 times the rate of production in 1912. Production in 1912 was 534,466,580 tons with a value at the mine of $695,606,071.

It is often asked, "How long will our coal supply last?" This question is answered by the following from the Papers on Conservation of Mineral Resources of the United States. * The figures are for data secured in 1907.

"The total reserve of easily accessible and now available coal is estimated at 1,382,780,000,000 tons. The assumption that a constant output has been reached would be utterly unwarranted. On the other hand, the adoption of the flat rate of annual increase of 7.36 per cent† would involve the improbable assumption that the marvelous record of the past and present will be maintained in the future and the production would continue to approximately double every decade. Using the waste allowance, on the basis of this constant rate of increase in production, the 1,382,780,000,000 tons available at the close of 1907 would be exhausted in one hundred and seven years, or by 2015 A. D. Against the use of the flat rate of increase it may well be contended that just as the rate of increase in population tends to diminish, so this rapid increase in per capita consumption of coal cannot persist, and a constant annual production will be reached. However, the figures set fifty years ago by statisticians for the probable constant annual production of coal in England have already been exceeded by over 160 per cent." . . . .

"Inasmuch as America leads the world not only in present production of coal, but also apparently possesses the greatest reserve and certainly is mining coal at much lower cost than any other country,the obvious tendency will be for European countries to look more and more to the United States for their coal supply. Therefore, while our present coal production and consumption are practically equivalent, the export of coal, unless prohibited by federal legislation, must eventually become a factor

*Campbell, M. R., and Parker, E. W., "Coal Fields of the U. S." Bull. 394, U. S. Geol. Survey, 1909.

†The average annual increase in coal production figured from the average of progressive decades.

and increase the coal production in the United States beyond the demands of home consumption. On the other hand, powerful influences will come to bear upon coal production, which favor lengthening the life of the supply. Thus it is to be hoped that with more improved methods in the utilization of coal the increased efficiency per unit may act as a factor in reducing coal consumption, and improved mining methods should likewise decrease the waste percentage. The increased utilization of waterpower should also tend to decrease coal consumption. Again, as soon as the end appears in sight prices will rise and production diminish, and that progressively. This interference with the law of decreasing increase produced by scarcity will of course prolong the life of our coal reserves, but at the same time will greatly hamper our industries that depend on this fuel.

"With so many indeterminate factors whose importance is realized but cannot be measured, prophecy must possess a questionable value."

A slightly different method of calculation shows that coal will be exhausted in 2027 A. D. * It is also stated that "if all the latent waterpowers in the country were harnessed within the next twenty years, it would probably prolong the life of the coal supply by about 80 years."

Price of Coal

It is often stated that the increasing price of coal will soon bring about the development of the peat deposits of the country. It is contended that the price is rapidly becoming prohibitive. The following tables give the prices of anthracite coal.

*Gannett, Henry., "Estimates of Future Coal Production." U. S. Geol. Survey, Bull. 394.

WHOLESALE PRICES ON ANTHRACITE COAL FROM 1900 TO 1914
CHICAGO MARKET*

Year	Sizes			
	Grate	Egg	Stove	Nut
1900—April (No discount)	$5.00	$5.25	$5.25	$5.25
1901—April (50c discount)	5.75	6.00	6.00	6.00
1902—April (50c. discount)	5.75	6.00	6.00	6.00
1903—April (50c. discount)	6.25	6.50	6.50	6.50
1904—April (50c. discount)	6.25	6.50	6.50	6.50
1905—April (50c. discount)	6.25	6.50	6.50	6.50
1906—April (No discount) (40c. discount in May)	6.25	6.50	6.50	6.50
1907—April (50c. discount)	6.25	6.50	6.50	6.50
1908—April (50c. discount)	6.25	6.50	6.50	6.50
1909—April (50c. discount)	6.25	6.50	6.50	6.50
1910—April (50c. discount)	6.25	6.50	6.50	6.50
1911—April (50c. discount)	6.25	6.50	6.50	6.75
1912—June (30c. discount)	6.50	6.75	6.75	7.00
1913—April (50c. discount)	6.50	6.75	6.75	7.00
1914—April (50c. discount)	6.60	6.85	6.85	7.10

The average annual wholesale prices of anthracite, stove sizes, in New York, per ton, according to Bradstreet's figures, have been as follows:†

Strike Year.	
1902	$6.97
1903	5.00
1904	4.88
1905	4.88
Strike Year.	
1906	4.95
1907	4.88
1908	4.88
Suspension.	
1909	4.88
1910	4.88
1911	4.88
Strike Year.	
1912	5.16
1913	5.10
1914 (Four months)	5.15

*These prices furnished by courtesy of E. J. Frautschi of the Madison Fuel Co., Madison, Wis.

†From, "The Retail Coalman." Chicago, June, 1914, p. 49.

In 23 years the variation has been only 17 per cent as compared with 20 to 200 per cent for 31 other commodities. The average of the various years has been taken as a basis. The year 1902 has been excluded from the calculation as the high prices of that year were caused by the prolonged strike which was directed against the independent operators and not the large producers, were not normal and have not been repeated.

Bradstreet's record of commodity prices also gives the following:

PRICE OF COAL

	July 1 1896	June 1 1910	Per Cent increase of Prices
Anthracite	$4.25	$5.00	17
Bituminous	2.75	3.15	15

From the preceding evidence we learn that:

1. Only ½ of 1 per cent of the original coal supply of the United States has been mined.

2. The quantity of coal still remaining to be mined is 3,061,000,000,000 tons.

3. These coal supplies will not be exhausted until at least 2020 A. D.

4. Influences tending to lengthen the life of the supply will come into play. Among these are improved methods of utilizing coal to increase efficiency per unit, improved methods to reduce mining wastes, and increased development and use of water powers.

5. The production of coal in 1912 was 534,466,580 tons whose spot value was $695,606,071—or $1.30 per ton.

6. In 23 years the price of coal has increased only 17 per cent.

Although Wisconsin contains no coal deposits, coal is and will continue to be abundantly supplied from outside sources at prices that have not yet become excessive or prohibitive. There is enough coal available for use to last at least over a hundred years. These conditions would seem to warrant the statement that little need will be felt to develop the peat deposits of Wisconsin in the near future. At least, the possibility of the exhaustion of our coal sup-

plies and the increasing price of coal are not yet apparent enough to urge the development of peat deposits in Wisconsin. These factors will not prompt peat development for some time to come.

Water Powers

Modern hydro-electric developments have made it possible to easily and cheaply convert the energy of falling water into electric energy and to send this energy over great distances to centers of consumption. Indeed, hydro-electric energy may now be purchased so cheaply that electricity is extensively used for lighting, heating cooking, smelting and ore-reduction, and in various kinds of industrial operations. Such use of electric energy is constantly growing.

While Wisconsin has no coal deposits, the state was endowed by Nature with valuable water-powers, inexhaustible and "eternal as the sunshine." Originating in the high lands of the north, in hundreds of lakes and springs, are large and rapid rivers which radiate in a southerly direction. To these Wisconsin owes no small part of her present prosperity. They have been the means of transporting the timber wealth to market, of furnishing energy to pulp and paper mills, and of supplying electric energy to a multiplicity of other industries. They are destined to play an important part in the future industrial development of the state and, when fully developed, will do much to make up for the absence of native coal deposits.

Without doubt, in the near future, energy derived from Wisconsin water power will replace energy from coal in a number of industrial operations, thus saving fuel and postponing the time when coal supplies will be exhausted or when the need for utilizing Wisconsin peat is felt.*

Peat Supply

In the following table some interesting suggestions are made concerning the peat resources of the United States and attention is called to "the very considerable source of wealth to the nation which is now lying entirely undeveloped in the swamps and bogs of the country."†

* For information concerning Wisconsin water powers see Bulletin XX, Wisconsin Geol. & Nat. Hist. Survey.

†Davis, C. A., "Peat Resources of the United States." Engineering Magazine, April. 1909. p. 87.

The total swamp area of the United States, exclusive of Alaska, is estimated to be ---------- 139,855 square miles

Of this, 8 per cent is assumed to have peat beds of good quality, or ---------- 11,188 square miles

The depth of peat over this area is assumed to average at least 9 feet, giving 200 tons of dry fuel per acre for each foot in depth, or a total of ---------- 12,888,500,000 tons

Value if converted into machine peat bricks at $3 per ton ---------- $38,665,700,000

Value if Coked and the By-Products of Distillation Saved

	Product in Tons	Value
Peat coke	3,608,800,000	$26,005,300,000*
		9,743,700,000†
Illuminating oils	257,800,000	4,471,200,000 (Illuminating and lubricating oils together)
Lubricating oils	90,200,000	
Paraffin wax	38,700,000	3,479,900,000
Phenol	167,500,000	66,315,100,000
Asphalt	25,800,000	824,900,000
Wood Alcohol	43,800,000	7,844,000,000
Acetic Acid	56,700,000	
Ammonium Sulphate	39,900,000	2,777,400,000
Combustible gases	738,400,000	6,501,300,000

* Charcoal price. † Coke prices.

These figures are interesting in that they form some sort of a basis for arriving at similar figures for Wisconsin peat deposits. There are perhaps two billion (2,000,000,000) tons of peat in this state, or $\frac{1}{6}$ of the total in the United States. Consequently, dividing the amounts given in the table by six will give approximate values for the deposits of peat in Wisconsin.

Financial Considerations

It is sometimes assumed that profit will always result when any idle natural resource, like a peat deposit, is developed. But this is not necessarily true, as has been proven by the financial failure of numerous peat projects in the past after considerable money had been spent in attempting their development. The commercial success of peat exploitation depends upon its financial feasibility more than upon any other factor, for men engage in industry for profit.

Very little information is available concerning the many items of cost entering into the development of a peat deposit and the manufacture and sale of the product. Information on these points is, of course, extremely necessary to have when forming judgments upon the practicability of any peat development scheme. A number of publications on peat contain data on some of these financial topics, but these relate almost exclusively to European plants. Study and analysis of these reports will throw some light on the possibility of a peat industry in Wisconsin. A number of plants have been erected in this country—and at least two in Wisconsin—but, after short periods, suspended operations because they could not be made financially profitable.

No doubt plenty of capital will be available for peat developments as soon as it has been demonstrated that funds invested in such enterprises are likely to produce returns. But at the present time peat development projects must be regarded as experimental, and investments in peat exploitation schemes must be looked upon as highly speculative.

Wisconsin's Situation

Wisconsin is located in a northerly climate. This means long, cold winters and extensive use of fuel for heating. Much fuel is also required to meet the demands of Wisconsin's industries. In such a situation "abundance of fuel means comfort and the smooth working of the social and industrial machine; scarcity means inconvenience, distress, and the dislocation of industries; absolute want of it would render the temperate regions of the earth uninhabitable."* No proof is required to show that fuel is an important and necessary article to the welfare of Wisconsin.

Coal is not found in Wisconsin. For its fuel supplies the state depends upon native wood and imported coal. Iowa, Illinois, and Indiana are the nearest coal producing states. The nearness of the Illinois coal fields and the facility with which Pennsylvania coal can be brought to Wisconsin makes coal easily obtainable.

Wisconsin is fortunately situated not only in being near coal supplies but also in having large stores of peat within its borders. The eventual exhaustion of coal supplies may force the development of Wisconsin peat resources. No doubt, every effort will be made to utilize them when necessity requires. But the fact that coal is still cheap and plentiful tends to postpone the time when such necessity

*Carter, W. E. H., "Peat Fuel Report, Bureau of Mines." Toronto, Canada, 1903.

becomes apparent. The development—if it ever starts—will be slow and gradual, but when it comes, Wisconsin will become an important peat producing state.

Length of Working Season

The climate of Wisconsin is such that peat deposits can only be worked for a period of six months each year; during the spring and summer. The time when frost leaves the ground marks the opening of the working season and freezing marks its close. Rainy weather shortens this period since operations on the bog must then be suspended. Such a short working season may be a handicap to peat developments because enterprises which can be carried on for only six months in each year are not attractive to investors. Idle capital brings no returns. On the other hand, the fact that peat must be manufactured and stored in the summer months and sold for heating purposes in the winter months tends to give all-the-year employment to the working force.

Just how important a factor the short working season may be in the development of a peat industry in Wisconsin remains to be determined. It ought not to limit the development of a peat deposit any more than that of any other seasonable undertaking like the harvesting of ice, the manufacture of brick, the manufacture of beet-sugar, etc.

Labor Conditions

Labor employed in peat manufacturing operations in Europe costs from 40 to 50 cents a day. The supply is drawn chiefly from farmers and the peasant classes. Boys and women work in the peat fields for very low wages. Peat work is carried on during periods when other work is not pressing.

In the United States farm labor is paid \$2.00 a day, and labor in general is better paid than in Europe. Indeed, at certain seasons when crops are plentiful, farm labor is scarce and commands high wages. In the western states farm hands are paid from \$3.00 to \$5.00 per day, board included, during crop harvesting time. It is quite evident that the cost of labor in Wisconsin will not permit of the production of peat fuel along the lines carried on in Europe. Mechanical methods, or rather large scale production methods would seem to be necessary to get costs low enough to put peat on a competitive basis with coal. Such machinery and mechanical methods

of handling have as yet not been developed. Little progress has been made in this direction because of the large outlay of capital required, and because business men can see little prospect of financial returns from such experiments.

Market

At the present time there is no market for peat in Wisconsin or in any of the surrounding states. In fact, there is no demand for peat in this country. This is due to several causes, chief among which are the following:

The country is now supplied generously with much better fuels and raw materials for which peat has been proposed as a substitute. They are still cheap, plentiful, and of high quality.

The people of Wisconsin are not familiar with peat or its properties.

That peat has any utility, or that it can replace certain other materials, has not yet been demonstrated satisfactorily.

On the other hand, peat has many disadvantages and at best is an inferior material.

Therefore, there will be little demand for peat until it has been demonstrated that other materials have become scarce, expensive or of low grade; that high grade peat material can be manufactured and sold cheaply in a competitive market; that it possesses inherent qualities of merit; that it can satisfactorily replace other materials at no great expense for alterations to existing equipment; that it will answer the purpose for which it is intended; that it has striking advantages over other raw materials; and that its disadvantages are negligible.

There probably will not be a market for peat in the immediate future.

Transportation Facilities

On account of the location of some peat deposits at points removed from transportation facilities, it will be necessary to provide means for getting the material out to markets. But when peat once becomes an article of commerce, there will be no difficulty in having it transported and in making the deposits accessible.

In general, it may be said that transportation facilities in Wisconsin are ample. There are over 8,000 miles of railroads in the state. The development of the peat industry will not be retarded on account of lack of transportation facilities.

Reclamation of Peat Lands for Agricultural Uses vs. Extraction of Peat Material

In a number of cases peat lands may be treated in one of two ways:

1. They may be drained and used for agricultural purposes, thus probably destroying the value of the deposit for fuel purposes.
2. They may be held until some future time when their development for fuel purposes may be made profitable because of the exhaustion of coal supplies and the gradually increasing price of coal.

It is rather difficult to determine which of these two methods of utilizing the peat lands of Wisconsin is the more profitable. Certain calculations have been made, however, which point to the conclusion that the wisest use of peat lands is for agricultural purposes, where such use is possible.*

Deterioration of Peat Deposits

Wisconsin peat deposits are subject to several influences which cause an impairment of their value. Rains and floods erode surrounding lands and wash soil and other ash-producing materials into the low places, thus contaminating the peat they contain and reducing its quality. Forest fires and marsh fires often ignite parts of a peat bed in dry seasons and the peat sometimes burns for long periods. Marsh fires, frequently smouldering for months, burn great holes deep into the deposit. This, of course, results in the destruction of a portion of the bog. Many peat areas in northern Wisconsin have been partly consumed by such fires. In some instances, too, drainage schemes, for the reclamation of the marsh for agricultural purposes, have altered the characteristics of the peat and forever destroyed its potential value as a raw material for fuel and other uses.

In considering future possibilities of any peat bog, such factors as those just mentioned must not be overlooked, for at the end of fifty years they may have altered the character of the deposit considerably.

*See Appendix B.

General Conclusions

Wisconsin possesses peat resources equal to those found anywhere. But at present none of them are developed. The marshes containing peat are practically useless, being waste land, except in a few cases where some of them are used for crops and for cranberry culture. Attempts have been made to utilize the peat in a few deposits for fuel and in the manufacture of paper-board, but the outcome proved unsatisfactory. Gasification of peat has also been attempted, but this, too, has failed to give results of commercial value. As yet, no large quantities of peat fuel or peat in any form have been produced and tried out thoroughly. Such efforts at peat development as have been made were abandoned after short periods. This evidently indicates that the peat material, as worked up under existing processes, did not prove to be a satisfactory product and that it could not compete with other better-known materials for which it was proposed as a substitute. Apparently, the material did not meet expectations. Failure in these efforts is largely due to the fact that the raw material could not be dried economically and because, after drying, the product was low grade and inefficient. No developments are under way at the present time. In fact, the peat industry has never gone beyond the experimental stage in Wisconsin.

The future of the peat industry in Wisconsin is hard to predict. It seems certain, however, that its development lies many years in the future. Little use will be found for peat until such times when other materials become scarce and expensive. At present such materials are still cheap, plentiful, easily obtained, and satisfactory. During coal strikes and coal famines some development of peat deposits may take place, as has been the case in the past. But such activity is quite likely to be merely temporary. Unless some radically new method of drying and working peat into usable shape economically is developed, the large amount of water in raw peat will be the chief barrier to its use. When it is realized that more than 90 per cent of the material in the bog is water, and less than 10 per cent usable material can be recovered, and that a large part of this 10 per cent is ash, we can see that at best, peat is a low grade and inferior material. The material recovered has about one half the heating value of coal and is from 8 to 16 times as bulky.

The peat lands of Wisconsin in a number of instances are much more likely to be drained and reclaimed for agricultural purposes than they are to be used for their potential fuel value.

APPENDICES

A. T. C. Chamberlin on Wisconsin Peat Deposits.

B. The Use of Peat for Fuel, versus Its Reclamation for Agricultural Purposes.

C. Peat Producer-Gas Plants in Europe.
   1. Use of Peat.
   2. Plant at Skabersjo, Sweden.
   3. Plant at Visby, Sweden.

D. Bibliography.

APPENDIX A

T. C. Chamberlin on Wisconsin Peat Deposits

Certain detailed observations on the structure of several marshes containing peat were made previous to the 1903 and 1908 Surveys. These are reported by T. C. Chamberlin in "Geology of Wisconsin," 1873-1879, Vol. 2, p. 242, and are reproduced below.

"The first marsh tested occupies portions of sections 28, 29, 30 and 32, town of Whitewater (T. 4, R. 15 E.). Ten borings were made along two lines, one across the marsh and one longitudinally.

1. The first boring was on a springy elevation, near the center of section 32, from which the line stretched northward across the marsh. The peat at this point was very much mixed with shells, travertine, and apparently some argillaceous material. Sandy clay was reached at a depth of 11 feet, 4 inches. A ditch near by exposed a washed surface of the upper portion from which were taken fresh water shells of the genera Sphaerium Planorbis, Limnæa, and Pupa, the smaller species of these genera being very abundant, the larger, rare. This shows that the peat is of lacustrine origin, and that at no distant day this has been a lake.

2. At 50 rods from the first boring, we find about equal proportions of shell-marl and peat. The following is the section:

Soft, watery, dark-reddish, marly peat	4 ft. 6 in.
Thin layer of whitish marl	2 in.
Peat as above	1 ft.
Hard, well-decomposed peat	4 ft.
Bluish clay, filled with pebbles at	9 ft. 8 in.

3. The third boring gave the following section:

Marly peat	4 ft.
Hard, compact peat	5 ft. 6 in.
Clay at	9 ft. 4 in.

The bottom of a ditch nearby contains calcerous sand, evidently washed from the peat.

4. The fourth boring gave 8 ft. 8 in. of reddish, partially decomposed marly peat, containing shells. Bottom blue clay as before.

A section exposed by a ditch between borings 4 and 5 gave 2 ft. of peat, succeeded by 4 in. of shell-marl mingled with peat.

5. The fifth boring showed 2 ft. of moderately decomposed marly peat as before, 3 ft. somewhat more compact, with hard blue clay at 5 ft.

The remaining borings were on a line from the S. E. qr. of the S. W. qr. of sec. 29, to the N. W. corner of the S. W. qr. of sec. 29.

6. The first two borings were made to ascertain the structure of a mound 6 feet high and about 50 feet in diameter. The boring at the base gave 3 feet of muck-like peat, with clay below; that in the top of the mound gave 7 feet 8 inches of peat, mingled with much travertine, with clay and sand mingled at the bottom, which is about 1½ feet above the bottom of the boring at the base, showing an accumulation of sand and clay beneath the mound, which undoubtedly owes its origin to a spring.

7. Thirty rods farther west, the chief boring showed 8 feet 4 inches of watery, partially decomposed peat, free from noticeable travertine or marl. Bottom blue clay.

8. The fourth boring, 60 rods from the last, showed 5 feet 6 inches of watery, partially decomposed peat, 3 feet 6 inches of a compact, close textured, reddish, well-decomposed peat, with blue clay at 9 feet.

9. The fifth boring showed a similar section, blue clay with shells being reached at 8 feet 4 inches.

The lower compact peat of the last two sections presented all the physical appearances of superior quality, being apparently free from calcerous material found so abundant in the first series. The marly peat will undoubtedly prove a good fertilizer, and is well adapted to the sandy soil of the neighboring farms.

At the head of Lake Geneva there is a small area of similar marly peat, 8 feet deep.

In section 20, town of Sugar Creek (T. 3, R. 16 E.), there is a peat marsh about one-fourth of a mile wide, which extends eastward for several miles, but is narrow. To the westward it widens and connects with an extensive marsh in the town of Richmond. The following is a typical section from the center of section 20:

1. Surface black and somewhat earthy.
2. Well-decomposed, dark peat of moderate compactness, 5 ft.
3. Firm, well-decomposed peat..4 ft.
4. Drab clay, mingled with peat, at..................................9 ft.

The narrowness of the marsh at this point, and its evident exposure to wash from the neighboring land, render it probable that

a portion of the firmness of this peat is due to very fine silt, that could not be detected by sight or touch. At other points the surroundings were more favorable.

Horicon marsh was tested near its south end, with the following meager results:

First boring:

1. Surface, loamy peat	
2. Coarse undecomposed peat	2 ft. 6 in.
3. Black peaty clay	1 ft. 6 in.
4. Blue clay	1 ft.
5. Gravel at	5 ft.

Second Boring:

1. Peaty soil	1 ft.
2. Yellow clay	3 ft.
3. Blue clay, lower part sandy	2 ft. 6 in.
4. Gravel at	6 ft. 6 in.

Third boring essentially the same. Probably other portions of the marsh would show more peat.

A marsh near Berlin, the peat of which, I was informed, had received a favorable opinion from judges at the east, was tested. It lies along the Fox river, whose inundation must be supposed to affect its quality. Three out of several borings will represent its nature:

First Boring:
1. At 1 ft. 6 in., fibrous, not well decomposed.
2. At 3 ft. 6 in., fibrous, not well decomposed, yellowish-brown
3. At 5 ft. 6 in., better decomposed, reddish.
4. At 6 ft., dark-greenish blue clay.
5. At 6 ft. 6 in., clayey sand.

Second Boring—near river:
1. At 1 ft., fibrous, loose, dark.
2. At 3 ft., layer of decomposed wood.
3. At 3 ft. 6 in., clay as above.

Third Boring—near center of marsh:
1. At 1 ft., dark, fine fibrous, soft, not well decomposed.
2. At 3 ft. 6 in., less fibrous, reddish.
3. At 5 ft. 9 in., clay as above.

One of the more interesting of the smaller marshes is found in the W. hf. of sec. 30, Beaver Dam (T. 11., R. 14 E.). There are per-

haps 80 acres of available peat. It is surrounded by timber and has no stream flowing through it, and was formerly a lake, as shown by the shells of Sphaerium, Paludina, and Helix, found in the underlying clay. At 8 rods from the edge, there were 4 feet of firm, dry, reddish, well-decomposed peat, underlaid by clay. Thirty rods from the edge, the following section was obtained:

1. At 3 ft., firm peat struck; that above, soft.
2. At 5 ft. 6 in., reddish, well-decomposed peat.
3. At 7 ft., firm, color of brown paper.
4. At 12 ft., clay and peat mixed.

At the center of marsh:

1. Upper portion as above.
2. At 6 ft., firm, red, fairly decomposed, apparently derived from wood.
3. At 12 ft., (length of auger) bottom not reached; material much resembling brown paper pulp; contained the shells mentioned above.

In the town of Calamus (T. 11, R. 13 E.), N. W. qr. of sec. 25, and S. W. qr. of sec. 24, lies a marsh of 200 acres. A small stream flows through it. The following may represent five borings of similar import:

1. At 2 ft., well-decomposed, firm, black.
2. At 3 ft., well-decomposed, firm, black.
3. At 5 ft., well-decomposed, firm, yellow.
4. At 5 ft., 9 in., well-decomposed, firm, color brown paper.
5. At 7 ft., well-decomposed, firm, color brown paper.
6. Blue marly clay, containing shells.

The peculiar brown material was found to be sandy in two of the borings.

In the town of Lake Mills, sec. 1 and 2, a large marsh, partially covered with tamarack, gave the following sections:

First—Nine rods from the edge:

1. At 4 ft., dark, well-decomposed.
2. At 7 ft. 6 in., dark, well-decomposed.
3. At 10 ft., reddish, woody, sandy.
4. At 11 ft., sandy, blue clay.

Second—Forty rods from the edge:

12 ft. of soft, wet, not well-decomposed, dark, reddish, woody peat.

No evidence of sand; bottom not reached.

Third—Nearer the edge:

1. At 6 ft., firm, half-decomposed, dark-reddish, woody fiber.
2. At 10 ft., dark, well-decomposed, firm, apparently excellent.
3. At 12 ft., sandy; bottom not reached.

As an example of the greater depth in tamarack marshes, I may give the section obtained in the smallest marsh tested during the summer, consisting of only a few acres, in W. hf. of S. E. qr. of sec. 11, Summit (T. 7, R. 17 E.). It was tested within six or eight rods of the edge, with the following result:

1. At 6 ft. 6 in., began to be wet.
2. At 10 ft. 8 in., spongy, undecomposed mosses.
3. At 11 ft. 8 in., still in peat; bottom not reached.

Tested in a dry ditch, nearer the edge, to a depth of over 13 ft., without finding bottom.

The foregoing may be taken as representing the average character of the open peat bogs of the region. There are deeper and more extensive deposits than the ones given—the selection of those to be tested having been controlled by the necessities of other departments of the survey.

Peat has been used in this region to some extent as a fertilizer, and always with good results. Its value is much increased when mingled with other kinds of fertilizers, and it is especially efficient in absorbing the liquid manures that are usually wasted. The good results of the few trials that have been made, corroborated as they are by experience elsewhere, and justified by reasoning from the nature of the peat, commend this subject to the earnest attention of our agriculturists. In reference to the last point, I may be allowed to present succinctly those properties of peat that render it valuable as a manure, chiefly on the high authority of Prof. S. W. Johnson:

1. It absorbs moisture as a liquid and a vapor, and so counteracts the effects of droughts, and makes it invaluable to the more arid soils. This hygroscopic property indicates a natural adaptation to use as a fertilizer rather than as a fuel, it being detrimental in the latter respect.

2. It improves the texture of the soil.

3. By its decay it furnishes ammonia and carbonic acid, and some mineral substances.

4. It assists in the disintegration of other substances in the soil.

5. It absorbs ammonia from the air, and thus furnishes it to the plants.

6. By its dark color it absorbs heat from the sun, and thus increases the temperature of the soil.

Attempts have been made to utilize it as a fuel at several points with varying success. In almost all cases it seems to have furnished a very fair fuel, and in some cases it is claimed to be equal to the best hard wood. The general tenor of the results, where machinery has been used, is unfavorable; where the simpler methods have been employed, the prospect is more encouraging. In reference to the want of entire success in the former case, I gather the following causes:

1. Too much is expected, and consequently too great expense is incurred and too great risks taken. Theoretical calculation readily shows immense profits, and leads to manufacturing on a false basis, unless large deductions are made for practical difficulties, and larger margins left for unforseen contingencies. The manufacture of peat in this state should only be undertaken on the basis of reasonable, not immense, profits, as the result of judicious and careful management.

2. The price of other kinds of fuel in some places leaves too small a margin for profit.

3. Errors in the selection of the marsh. The simple existence of peat of a suitable depth does not ensure a suitable quality. The eye and the fingers often reveal fatal impurities, and of those that pass the examination of the senses, chemical analysis will show that some are unsuitable. The proximity of a stream that habitually inundates the bog is prima facie cause for suspecting the peat to be impure.

4. Errors arising from using that which is too near the edge, top, or bottom of the bed. The edge and bottom are impure for obvious reasons. Before the surrounding country was cultivated, the top was as pure as other portions; but cultivation has immensely increased the amount of earth material carried into our marshes by the water, and thus rendered the surface peat more impure.

5. Errors in the manufacture. Prominent among these is the failure to suitably dry the peat. Much of it contains, when taken from the bed, ninety per cent of water. This must be reduced to about twenty before it becomes suitable fuel. The peculiar hygroscopic property of peat, which is one of its valuable qualities as a fertilizer, is a source of difficulty here. Our dry and windy climate is, however, favorable, and if this difficulty has been overcome elsewhere, it may most assuredly here.

6. Want of the best conveniences for burning it. Our stoves and furnaces are especially adapted to coal or wood, and although peat may be used in either, it is placed at a disadvantage. It must compete with them on their own ground.

7. Want of knowledge on the subject, and a natural indisposition to change habits.

These and other errors will readily be corrected by experience, and if the laudable efforts that are being made to develop this new source of fuel are sustained and encouraged by an enterprising public spirit, we may confidently anticipate a final success."

APPENDIX B

B—The Use of Peat Land for Fuel Vs. Its Reclamation for Agricultural Purposes

In writing upon the subject of "Use of Marsh Land for Peat Content," Hotchkiss, Griffith and Jones say, *

"Obviously the practicability of commercial utilization of a marsh for the production of peat fuel will depend chiefly upon the character and extent of the market, the size of the marsh, and the thickness and character of the peat. The market must be such as to warrant a reasonable profit on the investment. The marsh must be large enough to justify the installation of necessary apparatus, and the peat must have sufficient depth to permit economical working, and be clean enough to make a satisfactory quality of fuel.

"An acre of peat one foot thick will produce slightly more than 200 tons of finished peat. With this as a basis we can make certain reasonable assumptions and find the total profit per acre to be made when conditions are such as to permit development, and give the various assumed amounts of profit per ton, and the present value of this proft.

"1. Assuming that conditions will be such as to permit the development of peat for fuel in 50 years' time;

"2. Assuming net profits of $0.50 per ton and $1.00 per ton in the table, and $0.25; $0.50; and $1.00 per ton in the diagrams.

"3. Assuming 8 per cent interest, compounded annually, as the return necessary for capital invested in such a speculative venture, and

"4. Assuming that the rate of taxation will continue to be 1½ per cent of the true value throughout the fifty year period, the total profit per acre and the present value are readily computed and found to be as given in the following tables for various thicknesses of peat.

*Hotchkiss, Griffith, Jones, "Drainage Report of the Conservation Commission of Wisconsin," 1912, p. 54.

Thickness of peat	Tons per acre finished peat	Total net profit per acre at end of 50 year period	
		At 50 cts. per ton	At $1.00 per ton
6	1,200	$ 600	$1,200
9	1,800	900	1,800
12	2,400	1,200	2,400
15	3,000	1,500	3,000
18	3,600	1,800	3,600
21	4,200	2,100	4,200
24	4,800	2,400	4,800

"To find the present value of these profits, which are assumed to be returned at the end of 50 years, we must find what sums put at compound interest at the rate of the carrying charge—8 per cent for interest on investment and $1\frac{1}{2}$ per cent for taxes—will equal these various profits. These present values will give the price that might be paid per acre and return 8 per cent net interest after 50 years. The following table gives these figures with approximate accuracy.

Thickness of peat	Present Value Per Acre	
	At 50 cts. net profit per ton	At $1.00 net profit per ton
6	$ 7 05	$14.10
9	10.58	21.15
12	14.10	28.20
15	17.62	35.24
18	21.15	42.30
21	24.65	49.30
24	28.20	56.40

"If the carrying charge be figured at 6 per cent per annum—which would be amply large if the state were to hold such marshes as are in its possession until they became available for fuel purposes—the present value per acre would be as shown in the following table:"

Carrying Charge 6 Per Cent Per Annum

Thickness of Peat	Present Value Per Acre	
	At 50 c. Net Profit Per Ton	At $1.00 Net Profit Per Ton
6	$34.50	$69.00
9	51.75	103.50
12	69.00	138.00
15	86.25	172.50
18	103.50	207.00
21	120.75	241.50
24	138.00	276.00

"The following curves give in diagrammatic form the information contained in the tables: See Fig. 20.

"When peat is suitable for specially valuable uses, such as the manufacture of fibre board, its value is considerably greater than for use as fuel. Marshes of this kind should in all probability not be drained but kept for the more profitable use.

Concerning the use of this peat W. O. Hotchkiss* says as follows:

"Much of this peat land is suitable for drainage and use for agricultural purposes, but a large part of it probably never will be suitable for this purpose. If we have then, a given peat bog which might be used either for the manufacture of fuel or as agricultural land, the question which must be settled is, which use will be the most profitable and which will therefore be the course of the owner who wishes to conserve his property. We may make certain assumptions which will be fairly within reason. From these assumptions we can roughly estimate the amount of profit to be made by using the land for either purpose.

"Assumptions:

I. That commercial conditions will be such that peat can be profitably manufactured and sold at the end of 50 years at a price of $3.50 per ton, of which 50 cents may fairly be considered as profit.

II. That interest on the investment will be 6 per cent and that taxes will continue to average 1.1 per cent of the total value, as at present.

III. That the present value of peat land if held for fuel manufacturing will not increase in 50 years.

*Hotchkiss, W. O., Report of the State Conservation Commission of Wisconsin, 1911, p. 39.

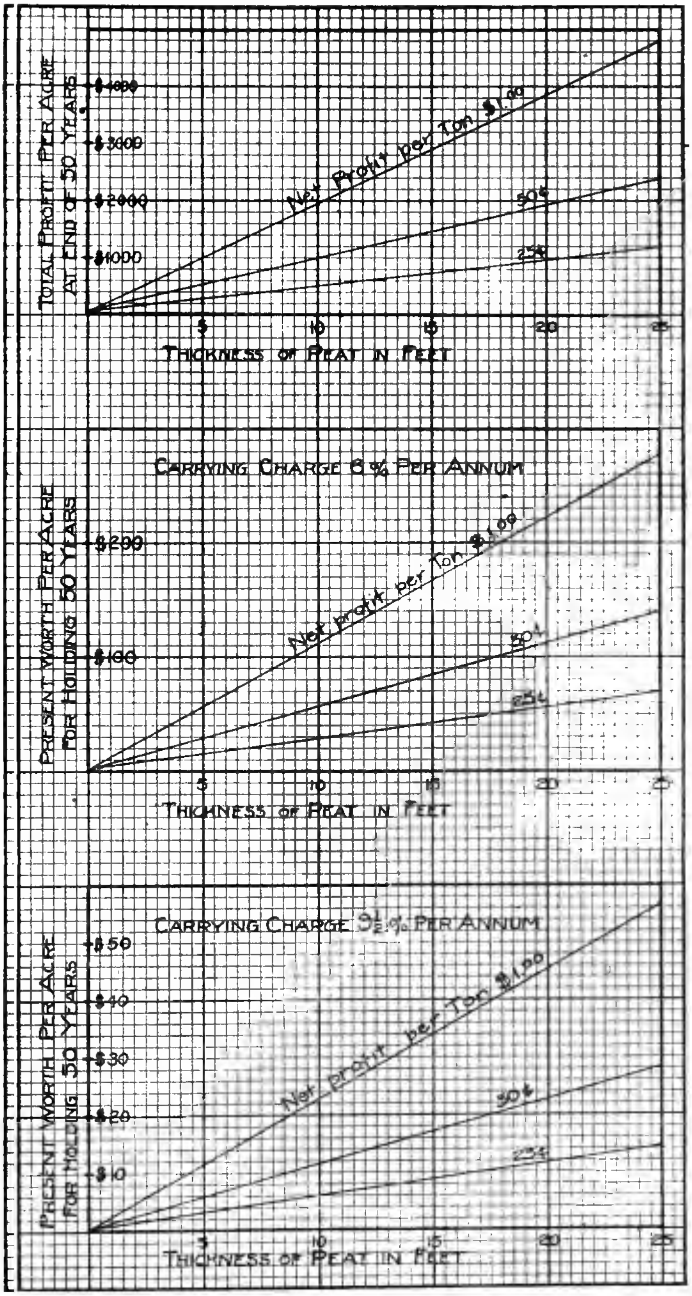


FIG. 20. PRESENT WORTH OF WISCONSIN PEAT LANDS

IV. That land can be drained and made available for agricultural purposes at a cost averaging $25 per acre and will be worth $150 per acre at the end of 50 years.

V. That the annual profit of farming those drained peat lands will average $7.00 per acre above taxes and interest on investment.

VI. That worked out peat land can be drained and fitted for agricultural purposes at a cost of $50.00 per acre and will then be worth $150 per acre at the end of the 50 year period.

VII. That $10.00 per acre and $40.00 per acre be taken as the limits of value of peat land at the present time.

"With these assumptions the relative profitableness for farm purposes and fuel manufacture can be estimated. These figures are necessarily only a rough example of the way in which the use of each peat bog should be studied. The total tonnage of finished peat and the present value of the land would be important factors in determining the use to which a particular bog is to be put. The profits in peat manufacture are entirely problematical and the figures assumed here would not be true in general.

PROFITS IF USED FOR AGRICULTURAL PURPOSES:		
Present value of peat lands	$10.00 to	$40.00
Cost of draining per acre	25.00	25.00
Cost ready for agricultural purposes	$35.00	$65.00
Average annual profit per acre	7.00	7.00
Profits for 50 years	$350.00	$350.00
Value of land at end of 50 years	150.00	150.00
	$500.00	$500.00
Subtract original cost	35.00	65.00
Total profit per acre in 50 years	$465.0(	$435.00
PROFITS IF USED FOR FUEL MANUFACTURING:		
Present value of peat lands	$10.00 to	$40.00
Cost of holding for 50 years, interest at 6%, taxes 1.1%, compounding at 7.1% for 50 years, gives as total investment per acre	$320.00	$1,280.00
Average tonnage of finished peat per acre		$1,250.00
Cost of holding 50 years per ton of finished peat	$0.26	$1.02
If cost of manufacturing and marketing are equal in both cases it is evident that if there were a net profit of 50c. in the first case there would be a loss of 26c. per ton in the second case providing the selling price were the same. If net profit in the first case were $1.00 there would be a profit of 24c. in the second.		
Profit per acre on peat at 50c. per ton	$625.00	$312.00 loss
Value per acre after removal of peat	100.00	100.00
Total profit in 50 years	$725.00 to	$212.00 net loss
Profit per acre on peat at $1.00 per ton	$1,250.00	$307.00
Value per acre after removal of peat	100.00	100.00
	$1,350.00	$407.00

"It is evident from these figures that there is a conservative profit in the use of peat land for agricultural purposes amounting to something better than $400 per acre in the course of the next 50 years. Under the most favorable conditions there is a speculative profit of $725 per acre and upwards in holding the peat for use as fuel. This speculative profit, however, disappears very rapidly as the initial investment in the land increases, owing to the great expense of holding. It will be evident on inspection that the assumptions made are, if anything, more favorable to the use of the peat bogs for fuel purposes than to their use as farm land. As a general proposition, it appears from present information that the wisest use of peat lands of the state that can be so used is for agricultural purposes. Other uses—for production of coke in by-product ovens, for paper, for litter for packing and stable use and for fertilizer filler—may make peat more valuable, but there is not data for making any statement with regard to this at present."

APPENDIX C

Peat Producer-Gas Plants in Europe

The following descriptions of two European peat plants using peat for the generation of power by means of converting it into producer-gas are interesting and were taken from a report by R. H. Fernald in Bulletin 4, United States Department of the Interior, Bureau of Mines, 1911, p. 21.

Use of Peat

"Among the most interesting producer-gas plants in Europe are those utilizing peat for fuel. The peat resources of Europe are extensive and are being rapidly developed. In many countries piles of peat dug for household use may be seen from the railroad trains. In some countries this fuel has thus far been used entirely for domestic purposes, but in others peat forms the main fuel supply for power and manufacturing plants.

"The bogs of Ireland have for generations supplied peat for domestic fires, but, although the bogs are extensive, the peat has not been used much for generating power. In 1908, however, projects were being considered that involve the erection of extensive power plants in the bogs of central Ireland and the transmission of electric current to Dublin.

"Peat has been most largely used in Holland, Austria, Hermany, Denmark, Norway, Sweden, Finland, and Russia. In Holland, peat has been used for hundreds of years and the bogs have yielded large returns. By the methods pursued, not only is the peat utilized but the bog is left in excellent condition for agriculture.

"In Austria and Germany much progress has been made in utilizing peat, especially in the manufacture of peat coke and the making of sulphate of ammonia from peat by means of by-product recovery plants. Doctors Frank and Caro have done much to advance ammonia recovery by their process of gasifying peat in a mixture of air and superheated steam. They find it possible to gasify peat containing 50 to 55 per cent water, thus saving much of the time usually required for drying. Although much of the peat thus far used in these by-product plants contains only about 1 per cent

nitrogen, the returns have been surprisingly good, 40 or more pounds of sulphate of ammonia being obtained from each ton of peat fired.

"Doctors Frank and Caro state that from an English peat they obtained 118 pounds of sulphate of ammonia per ton of water-free peat. The gas from each ton of fuel generated all the steam required by the plant and produced power equivalent to 480 horsepower-hours.

"Doctor Frank believes that the process will pay with peat containing only 1 per cent nitrogen. The peats of the United States contain a much larger amount of nitrogen than those of Europe, and Doctor Frank is confident that this process, if applied to them, will prove very profitable.

"Messrs. Crossley Brothers report that at their works they recovered 134 pounds of sulphate of ammonia from a ton of chemically dry peat containing 2.24 per cent nitrogen. They also report that 1,000 horsepower-hours could be obtained from the gas from each ton of dry peat.

"Since the supply of bituminous coal or lignite is large in some countries, the necessity for utilizing the peat resources is not so great in them as in Norway, Sweden, Denmark, and Finland. A recent report shows that Russia leads in the production of peat for generating power, the quantity dug reaching 4,000,000 or 5,000,000 tons a year.

"The principal manufacturers of gas producers and producer-gas engines are now putting out double-zone suction producers, designed especially to use peat. These producers burn peat containing 20 to 30 per cent moisture, and seem to work easily and give a rich, clean gas.

"These small peat-burning producer plants for generating power are widely used in Europe, although the first plant of this type was installed no longer ago than 1904.

Peat Producer-Gas Plant at Skabersjo, Sweden

"The first plant, which stands in the center of a peat bog near Skabersjo, Sweden, is of special interest. Its capacity is only 300 horsepower, and it is situated about 3 miles from the town to which it supplies the electricity. Half of the plant (150 horsepower) was erected in 1904 and the other half in 1906.

"The plant is probably both the first and the smallest producer-gas installation located at a bog and generating high-voltage current

for transmission to a point some distance away. In 1908 the plant comprised two suction producers especially designed to burn peat, and rated at 150 horsepower each, and two engines direct connected to alternating-current three-phase generators, which were running smoothly in parallel at the time of the writer's visit. The 3,000 volt current is transmitted to the town, where it is used during the day for lighting the shops and for driving shop motors and at night for lighting streets and residences. One unit is in operation from 5:30 a. m. to 6 p. m. and the other from 5:30 a. m. to 11 p. m. every day. The charge for residence lighting is 9 cents per kilowatt-hour.

"A 35-horsepower peat machine is used for preparing the fuel. This is driven by an electric motor supplied with current from the power plant on the bog. As only 750 tons of dry peat are required per year, there is no attempt to work the plant to its maximum. As there is no difficulty in getting out in the working season, which in this locality is from April 15 to September 1, all the peat needed for a year, only 14 men, local farmers, are employed, and they work as little or as much as they please. They receive about 50 cents a day each and get out 20 tons of peat a day.

"Bituminous coal at Skabersjo costs $3.75 a ton. The dry peat delivered on the platform of the producer plant costs only 80 cents a ton.

The general details of the plant are summarized thus:

Number of producers: 2

Make of producers: Koerting.

Type of producers: Suction, specially designed for burning peat.

Rated capacity of producers: 150 horsepower each.

Number of engines: 2.

Make of engines: Koerting.

Type of engines: Twin, horizontal, single-acting, 4-cycle.

Rated capacity of engines: 150 horsepower each.

Use of power: Motors in shops and for lighting the shops, streets and residences at town 3 miles from the plant.

Hours per day: 5:30 a. m. to 6 p. m. for one engine; 5:30 a. m. to 11 p. m. for the other.

Number of men required to operate plant: 3 on day shift (1 supplying fuel, 1 in the producer room, and 1 in the engine room); 2 at night.

Method of charging: Charge once an hour.

Kind of fuel and cost: Peat costing krone (80 cents) a ton at the producer.

Fuel used: 2 kilograms per horsepower-hour.

"No fan is used for suction at this plant, the gas being drawn from the producer by the suction strokes of the engines.

"The only trouble experienced with the producers has been from the lining, and this has been slight.

"It has been found that the plants using this peat operate best with 30 per cent moisture in the fuel; with less the fuel is too dry and steam is required. More than 30 per cent moisture is too much.

"The bog is worked by the old type of machine; that is, the peat is shoveled onto the conveyor. The machine is driven by an electric motor, taking current that has passed through a transformer placed on the bog close to the machine.

"The average depth of this bog is about 2 meters (6.7 feet), and at the present rate of digging will last about fifty years. It is estimated that 1 cubic meter (1.3 yards) of peat in the bog supplies about 100 to 110 kilograms (220 to 243 pounds) of peat containing 25 to 30 per cent of moisture.

"The plant was running very smoothly and required little attention.

Peat Producer-Gas Plant at Visby, Sweden

"Another peat burning plant that is attracting the attention of engineers interested in producer-gas development is at a cement works at Visby, Gothland, Sweden. At the time of the writer's visit, the capacity of this plant was about to be increased from 250 to 1,500 horsepower.

In 1908 the general details of the plant at Visby were as follows:

Number of producers: 1.

Make of producers: Koerting (for peat).

Type of producer: Suction; fan exhausts gas and forces it to engine.

Rated capacity of producer: 250 horsepower.

Number of engines: 1 twin unit.

Make of engine: Koerting.

Type of engine: Horizontal, single-cylinder, single-acting, twin.

Rated capacity of engine: 250 horsepower.

Load carried: Full.

Use of power: Driving machinery in cement works.

Hours of work per day: 10.

Kind of fuel, cost, etc.: Peat, costing, with old methods of collecting, $1.35 per ton on cars at bog. English anthracite costs nearly $6.00 per ton.

"The dry peat from the old machine at the bog is more or less broken and varies in size from pieces 12 x 4 x 2 inches to dust. The peat is brought on cars from the bog and dropped into a big concrete storage house, well ventilated by slits in the walls. From this storage house boys take the peat to a crusher, first shaking it out on forks to deposit all pieces of dust. The crusher breaks it into pieces from 1 to 3 inches in diameter, which are carried by a mechanical conveyor to the bins over the producer.

"Boys weigh each wheelbarrow load before dumping it into the crusher. During my stay about the plant (about one and one-half hours) nobody went near the producer. The engines were running nicely and no troubles were apparent. There was serious trouble from tar in the engines when the plant was first started, but this had been overcome.

"The dry peat usually contains about 25 per cent of moisture, but at times contains 40 per cent.

Preparation of Peat at Visby

"The working season at Visby is from April 15 to August 8, and all the peat should be dry and in the storage bins by October 1. At the time of the writer's visit, hundreds of tons of peat in various stages of drying were scattered over the bog.

"The old peat machine, installed in 1902, is of 38 horsepower; that is, the boiler and engine which operate it have about that capacity. The peat is shoveled onto the conveyor, and men with a series of knives cut the strips from the mixer into the required lengths. The peat blocks are irregular in size and always break more or less during drying. Originally, 26 men were required for an output of 30 tons of "dry" peat (containing 25 per cent moisture) in a ten-hour day; later the number of men was reduced to 23. The machine cost $3,375.

"The new machine, installed in the spring of 1908, is the first of its type, and when seen was, of course, still somewhat experimental. It is of 42 horsepower capacity, cost $7,155, and with a crew of 10 men turns out 60 tons of "dry" peat in a ten-hour day. The crew comprises 1 engineer and 1 helper, 1 digger (at the buckets), 4 field-press men, 2 track layers, and 1 trolley man who couples and guides the cars.

"With the new machine the bog is dug by a bucket dredge and conveyor, passes through shredding and mixing devices, and runs into the cars as a pasty mass. It is then taken to the drying field, dumped

into a frame on the ground, leveled with hoes, rolled and divided into bricks. The longitudinal divisions are made by blades on the roller, the transverse are made by a 3-disk cutter pushed by a man. The bricks measure about 8 or 10 inches long, 4 inches wide, and 2 inches thick and weigh (when containing 25 per cent moisture) 1.75 pounds each.

"The average depth of the bog is approximately 6.7 feet, and the output of dry peat is about 370 pounds per cubic yard of peat from the bog.

"About thirty days are required for drying—two weeks before piling and two weeks after. The women who pile the peat receive 12.5 cents per 1,000 pieces, and their average wage is 47.5 cents to 54 cents per day. The cables that drag the cars of peat about the field are long and break frequently at the bends made by the car grips. With the old systems of work, horses are used to handle the cars.

"To load the peat at the railroad, the small cars are hauled up an incline and dumped into the railroad cars. As the hauling requires the attention of three or four men, it is planned to introduce gas-engine haulage. The fine broken peat is used in the steam boiler and makes an excellent fuel."

APPENDIX D

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